An Investigation into the Effects of Using Dynamic Representation to Reflect Users' Emotional States During Physical Activity

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Dynamic Representation of Emotional States During Physical Activity

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Declaration

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Abstract

Many people struggle to maintain exercise routines (Biddle and Fox, 1989). Affective state (emotion, mood and sentiment) plays a key role in supporting or undermining intentions to exercise (Hanin, 2000). Presenting users with representations of their emotions can result in positive adjustments to their behavior (Brave and Nass, 2002). This project aimed to evaluate the impact of running with such a representation on a user's positivity during a run, and upon its completion.

A mobile application, EmotiRun, was iteratively designed to capture user feelings whilst running via self-reporting functionality; using this to dynamically represent inferences made of the positivity of the positivity of a user's emotional state.

A user study with EmotiRun didn't reveal significant differences in positivity with an 'emotional' display present. Participants did however note their awareness of the dynamic representation changing, and its potential as a motivational cue. The design and evaluation context in the physical setting of running are considered in relation to the fields of Affective Computing, and more broadly Human Computer Interaction. Further work is proposed to build upon the study method and design approach, of in-situ real-time self-reporting for physical activities.

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Chapter 1

Introduction

This project will examine the effects that presenting a user with a dynamic representation of their emotional state may have on their running behaviour and attitudes towards running. For this to be investigated EmotiRun, a mobile application capable of capturing emotions and making inferences for this dynamic representation, was created. A number of user studies were then conducted to understand the impacts of using the application on an individual’s running experience.

This chapter presents the rationale for the project, highlighting where it may provide new insights about the representation of affective state on subjective reports about an experience. This overview will serve as the initial grounding for the work to follow, presenting the key discussions that will be explored throughout the project.

1.1 Project Rationale

The behaviour of an individual is heavily influenced by their affective state (Hollis, Konrad and Whittaker, 2015). Emotions and moods contribute to a human's decision making process, which can result in either positive or negative consequences for subsequent behaviour. For this reason, over the past decade researchers within the Human Computer Interaction field have had a keen interest in trying to detect, analyse and manipulate user affect through the use of physiological sensors (Healey, 2014; Partala and Surakka, 2003), behavioural biometric data (van der Wal and Kowalczyk, 2013), and self-reporting tools (Lang, 1980; McNair, Lorr, and Droppleman, 1971; Watson, Clark, and Tellegen, 1988). This project considers how knowledge about moment-to-moment emotions might contribute to an overall attitude or "sentiment" towards a particular experience, namely running.

The initial stage in this project will be to detect and analyse the user's current emotional state. Current emotion detection tools have had success in identifying distinguished user states in real-time. Epp, Lippold and Mandryk (2011) analysed the rhythm of the typing patterns of users as they performed their daily computer tasks. Through this they were able to create classifiers from which 15 emotional states could be inferred, including confidence, nervousness and excitement. Pulse and skin conductance response has also been investigated, by Takahashi (2009), to evaluate positive, negative and normal emotions. Most of the research has consisted of experiments that have purposefully used stimuli to create situations where emotions are heightened to enable easier data capture. It is therefore unclear how successful these tools may be in recognising specific emotions in naturalistic settings.

Several tools used in detection have also been deemed as obtrusive and invasive, causing doubt of their usability in real-world situations. Self-reporting, whereby users provide their own emotional data input, can be seen as an alternative non-invasive approach. Various self-reporting scales and techniques have been developed, such as that of the Positive and Negative Affect Schedule created by Watson, Clark, and Tellegen (1988), and a pictorial representation, called the Self-Assessment Manikin, by Lang (1980). Whilst these scales have been successfully validated, their approach to data collection is in principle somewhat limited in that the emotions captured are only those that a user wishes to record and are conscious of. This project will further consider the relative merits of emotional detection tools to identify a suitable approach for use in a practical and natural context of interaction, in particular where physical exertion is required.

Many studies on emotion detection and inference also appear to focus on experiments hosted in a laboratory, where users remain largely inactive. A potential decision factor in this, particularly for studies using physiological sensors, is that it has been thought that collected data could be skewed by physical exertion. For example, if heart rate is the chosen measurement of detection this will naturally increase during exercise as the heart speeds up to pump additional oxygen to the muscles. However Clarke et al. (2005) conducted a study, measuring changes in heart rate and skin conductance, which noted that no adjustments to account for physical activity are required for real-time emotion inference systems. Although self-reporting mechanisms and behavioural biometric data are not noticeably impacted by the level of activity, it can be difficult to implement supporting systems that are sufficiently robust to allow for the accurate capture of data in an active setting. The following chapters of this project will therefore explore and aim to resolve the implementation challenges of creating a system that can be used whilst an individual is undertaking exercise, specifically running.

The next part of the project will utilise collected data to dynamically represent the user's current emotional state. A first step in this process will be to identify and select a method for inferring and modelling emotions. Previous work highlights two approaches; basic emotions theory (Ekman, 1992; Kobayashi and Hara, 1997) where a core set of emotions are seen to be a part of our biological profile (Oatley and Jenkins, 1996), and componential theory where continuous dimensions of emotional variance are used (Liapis et al., 2015; Partala and Surakka, 2003; Sonderegger et al., 2016; Scherer, 2009). The use of the dimensions of arousal and valence is particularly prevalent, seen in recent work by Mou, Gunes and Patras (2016) and Povolny et al. (2016).

The modelled emotions will subsequently be embodied in a dynamic ‘emotional’ display. Studies by Bouchard et al. (2012) and Snyder et al. (2015), showed that representations of a user's emotional state can provide insightful feedback to a user that can positively influence their behaviour. Snyder et al. (2015) created MoodLight as a means to help people cope with unwanted anxiety. MoodLight presents users with a red light when they are highly aroused, with users actively seeking to calm themselves to change the colour of the light to blue, reflecting a more relaxed state. The idea is that people may be better able to cope with unwanted affect if they are supported in explicitly focusing on its control. This ambient lighting system that responds to the biosensor data of an individual's current state of arousal therefore provides an interesting approach that will be considered for use in this project. Other alternatives such as the use of complex and simplistic emotional agents will also be explored, as these may be more complementary to the type of data captured from the selected emotion detection tool.

This project aims to investigate the potential impact representing a user's state has on their overall perception of a physical workout. If the impact is positive, the concept could be incorporated into future designs of fitness trackers to provide an additional element of self-monitoring for users, allowing them to evaluate and compare their physical statistics with their overall mood or real-time emotional states. Over time this could lead to users thinking more positively about exercise and therefore engaging in it more frequently. Researchers could also benefit from using the tool to conduct more active studies of emotion detection and representation, which are a potentially closer replication of real-world situations.

Concluding the project rationale, the main aim of the project is to investigate whether providing real-time feedback of a user’s emotional state influences their overall perception of their workout. To support this aim a mobile application that can be used to collect data during physical activity was iteratively designed, created and tested in a real-world setting.

1.2 Dissertation Overview

In Chapter 2, the literature surrounding the topics to be covered in this project will be discussed, providing the theoretical foundation for the work to follow. Theories of emotion (Clore and Ortony, 2013; Oatley and Jenkins, 1996) and affective terminology (Brave and Nass, 2002) will initially be explored, prior to the presentation of potential indicators of emotional state, where self-reporting tools are seen to show promise in the physical context of running. Approaches of modelling and representing emotional states are then discussed, with the dimensions of arousal and valence (Mou, Gunes and Patras, 2016; Povolny et al., 2016) and the use of light (Snyder et al., 2015) as a display medium highlighted.

Chapter 3 further explores the interaction between emotions and exercise through an initial user study. A core aim of this study was to observe runners in a natural setting to identify and resolve potential system design challenges in a physical context. From this several research questions will be presented and addressed throughout the project:

Research Question 1: How could a user’s emotional state be dynamically represented, for user interpretation, in an active setting?

Research Question 2: How could we collect data input from users in a non-obtrusive and non-invasive way, in an active setting?

Research Question 3: How might we use collected data to make inferences of a user’s emotional state within a two-dimensional space of valence and arousal?

Research Question 4: Are users affected by emotional state representations displayed ‘during-run’?

Research Question 5: Do users view a run more positively ‘post-run’ as a result of being exposed to representations of their emotional state?

Chapter 4 will establish the design framework for EmotiRun, ensuring the noted functionality enables the research questions to be addressed. A storyboard of the process of running is first presented, drawing upon findings from Chapter 3. The initial requirements, a translation of this, will then be described, before a high-level model of the system is specified. Individual components of this model will be discussed in more detail, with a focus placed on the user interface design and the adaptations required of EmotiRun to enable its operation within a physical environment.

Chapter 5 presents the implementation of EmotiRun, reflecting the decisions made in Chapter 4. EmotiRun was to be used in the main user study, and was iteratively updated to improve system usability and performance. An alternative Arduino-based prototype system that was initially explored is also presented in this chapter.

Chapter 6 presents the motivation and method of the main user study, discussing the study’s design and results in terms of the research questions. The results will be collected and organised to allow new insights to be identified for further analysis.

Chapter 7 uses the initial analysis from Chapter 6 to draw conclusions on the posed research questions. It will highlight the project’s contribution within the field of Affective Computing, whilst evaluating limiting factors of the project and potential extensions for further related work.

Chapter 2

Literature Survey

The basis of this project lies in the creation of a system that dynamically represents a user's emotional state, by detecting and capturing possible emotion indicators from which inferences of state could be made. To enable the design and implementation of such a system this chapter develops an initial set of concepts of emotion, which is routed within Psychology. It then brings in Human Computer Interaction and Affective Computing perspectives on emotion in interaction. As the proposed context of the project includes user testing in a physical environment it also explores constraints on validity from the Sports Science field.

Whilst many methods for detecting, inferring and representing emotional state in previous work may not initially seem plausible in the context of physical exertion, it is useful to evaluate individual features that could be used in the design of a new system.

The review concludes by setting a conceptual agenda for a field study of runners in action to be reported in Chapter 3. It also outlines possible research objectives for the project that will provide greater focus for following phases.

2.1 Defining Emotions

Whilst there has been extensive research into emotion, researchers are yet to agree on a universal definition as there is difficulty in providing this without the use of conflicting ideas (English and English, 1958; Oatley and Johnson-Laird, 2014). However, it is acknowledged that experiencing and responding to emotions is effected through neural and chemical actions within the brain (Oatley and Jenkins, 1996), and that these create system-wide influences on thought and action.

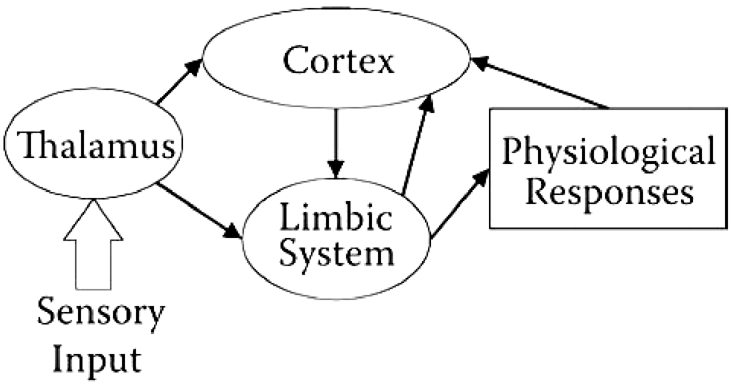

Figure 1.1: Neurological Structure of Emotion

2.1.1 Emotional States Influence Cognition

Brave and Nass' (2002) model, adapted from LeDoux's (1998) evaluation work on neuropsychology, provides an overview of the parts of the brain perceived to be associated with emotion, shown in Figure 1.1. The model highlights three areas of the brain: the thalamus, the cortex, and the limbic system. The limbic system throughout literature (Brave and Nass, 2002; Gobet, Chassy and Bilalíc, 2011) has been noted as the key source of emotion, and plays an essential role in how people interpret sensory input from their surrounding environment. However, there are multiple connections between components of the model, which contribute to the rapid and varying adaptation to external stimuli (Gobet, Chassy and Bilalić, 2011; Picard, 1996).

When a person interacts with stimuli in an environment, incoming sensory information is first processed by the thalamus (Gobet, Chassy and Bilalić, 2011). This information is then sent by the thalamus to both the cortex and the limbic system. The higher-level cognitive processing is carried out by the cortex, whilst the limbic system continuously evaluates the goals and needs of an individual in relation to the given inputs. If correlation is found, signals are sent to the body, activating physiological responses, such as heart rate and hormone changes (Oatley and Jenkins, 1996). Signals from the aroused limbic system are also relayed to the cortex resulting in biased cognitive processing of functions such as attention and working memory. The processing within the cortex is additionally influenced by the physiological responses of the body, and any relevant emotional signals, as a result of cognitive processing, are sent to the limbic system (Brave and Nass, 2002).

These relationships highlight the influence that emotions have on cognition. Review work by Forgas (1991) further suggests that a person's emotional state influences their observations of their own behaviour, and the interaction between the different parts of the brain aids them in making rational decisions (Damasio, 1994). Dependent on the stimuli presented certain emotions can also increase the probability of a specific emotional response (Frijda, 1993).

Of particular interest is a study by Fredrickson and Levenson (1998), where it has been found that positive emotions help lessen continuing negative emotions and their associated damaging physiological responses, such as increased blood pressure. Being in a positive emotional state also appears to enable greater efficiency in cognitive processing, as studies by Isen, Daubman and Nowicki (1987) and Isen (2008) have shown.

An understanding of the functionality of the brain and how it processes emotional signals shows the complexity and uncertainty a physiological approach to measuring emotion may have.

2.1.2 Emotions as Composite Dynamic States

Whilst literature does not present a universal concept of emotion, there are two main groups of theories that most researchers identify with. One of these is referred to as the componential theory (Clore and Ortony, 2013), whereby researchers view emotion as a set of components that can be individually distinguished as a variance of a specified dimension (Brave and Nass, 2002; Oatley and Jenkins, 1996). Most commonly this is viewed as being pin-pointed on a dimensional scale of valence (positive to negative) and arousal (intensity of the emotion from low to high) (Brave and Nass, 2002; Lang, 1995). This theory identifies that there are few universal emotions with most emotions being learnt socially, and therefore varying across cultures where there are differing levels of expression (Oatley and Jenkins, 1996). Componential theory has also been noted by Evans (2003) as being associated with higher cognitive emotions, and therefore more cortical processing. Using this approach allows greater flexibility in modelling and for a finer granularity of precision to be applied to distinguish more unique sets of 'mixed' emotions.

Contrasting is the basic emotions theory, where theorists believe that there is a base set of emotions that are part of our biological profile, evolved through natural selection (Oatley and Jenkins, 1996), and are shared across humanity. This supports the research outlined earlier which revealed the parts of the brain that are directly associated with emotional processing. However, there is much discrepancy over what is defined as a core basic emotion, which is both distinct and prevalent. To gain variations of this core set, to identify new emotions, different basic emotions can be combined (Ekman and Friesen, 1975), or emerge during social interactions with environmental stimuli (Gobet, Chassy and Bilalić, 2011). In comparison to componential theories of emotion, basic emotions are likely to be more identifiable and hence easier to measure (Brave and Nass, 2002). Representation in this form may also be simpler for a user to recognise and interpret, particularly in the physical context of the user studies proposed for this project.

The model by Brave and Nass (2002), shown in Figure 1.1, highlights that emotion can be seen as a two-fold concept, consisting of emotional experience and emotional response. Response is referenced in terms of the physiological changes that occur within the body, whereas emotional experience is stated to occur when an individual becomes aware of these changes (Gobet, Chassy and Bilalić, 2011). As such, gaining an understanding of the other concepts relating to emotion that differ in duration will be useful in defining which aspects will aim to be detected and represented in the context of this project.

2.1.3 Mood

Emotions are often identified as being limited in duration; suggested as lasting between 0.5

and 4 seconds by Richard Levenson (1988). As a result emotions are also seen to be of an elevated intensity (Schwarz and Clore, 2007), and therefore more likely to be unconcealed as a facial or body response (Russell and Barrett, 1999). An example could be a person who is accidently bumped into in the street. The negative emotion experienced as a result of this encounter is unlikely to be prolonged, particularly if the collision causes minimal pain, however they may grimace at the initial impact. In comparison, mood can be observed as a longer-term, low-intensity, background state of the emotional system when there are no external factors currently stimulating it (Gobet, Chassy and Bilalić, 2011). Mood can also be identified as being a tendency to act, rather than an automatic response as associated with emotions.

Mood is additionally distinct in that it is infrequently correlated to a specific stimulus (Morris, 1992), providing a more generic valence state (Morris, 1989; Schwarz and Clore, 2007). Whereas emotions are object-directed (Frijda, 1994), involving interactions with a specific object. An individual can therefore be upset about a particular event, but still perceive themselves to be in a positive mood overall. However there is interconnectivity between the two concepts as an emotional episode can change our mood after the emotion wanes, and there is no further interactivity with the stimulus. Continuous reflection on the emotions that resulted in the current mood (Evans, 2003) as well as the mood itself biases an individual's reactions to future stimuli (Clore et al., 2001) in a 'mood-consistent' way, as stated by Brave and Nass (2002).

2.1.4 Sentiment

Another concept related to emotion that needs to be considered for this project is that of sentiment; whereby exposure to specific objects or events is associated with inducing a particular emotional state, due to previous interaction encounters. For example, if an individual is nervous about hurting themselves as a result of running due to a former running injury, they may have attached a sentiment to the physical act, thus becoming more nervous generally during their next run. They may even become nervous prior to the run in the expectation that this could be a future emotional state. Whilst it increases the chances of them feeling nervous it is not certain that they will react in this way. Another individual who does not hold the same sentiment towards running may also become nervous of injuring themselves.

In comparison to emotions, sentiment is of potentially limitless duration and therefore heavily influences an individual's motivation to engage with certain objects (Brave and Nass, 2002). This biasing, alike to mood, means individuals are more likely to act in alignment with perceived sentiments towards an object that have been reflected upon and consolidated over a long period of time.

Sentiment towards an object can be established through personal experiences of direct interaction, and through social influence, where other individual's viewpoints are embraced (Brave and Nass, 2002). The concept of sentiment will need to be considered when selecting and engaging individuals in this project's user studies to understand their initial feelings towards running and physical exercise. It will also be contemplated as a measurement of interest to understand the impact of presenting a user with a representation of their emotional state.

This section has noted that emotions can be influenced by both mood and sentiment, but previous emotional states can also influence subsequent emotions through habituation and the system of excitation transfer (Brave and Nass, 2002).

Habituation is the process in which the arousal of an individual's emotional state decays over time if they are repeatedly exposed to it at a similar level. An individual comes to expect the emotional state and as a result does not experience the initial intensity felt on the first occurrence. This can be related to the laws of emotions as proposed by Frijda (1988), whereby emotional states are elicited by the changes in environmental factors rather than just their presence, with larger changes causing more intense emotional responses.

In contrast, is the mechanism of excitation transfer referenced by Zillmann (1991). This is based on the concept that after a stimulus has caused an emotional state, this state proceeds to exist but decreases in arousal over a period of time. If during this period of decay another stimulus triggers an emotion, the residue of the current emotional state will be combined with the incoming emotional signals, causing a heightened reaction to the stimulus. An example of this is if a runner experiences pain resulting in a negative emotional state, rapidly followed by a happy state as they finish a race. The negative emotional state will still minimally exist and potentially decrease the experience of the successive positive emotions. This concurs with the study by Fredrickson and Levenson (1998) referenced earlier, where positive emotions were found to contribute to reducing continuing negative emotional states.

Having defined the viewpoint of emotion that will be taken within this project, we can now explore potential indicators of emotional state.

2.2 Indicators of Emotional State

Individuals have been observed in expressing their emotional state in a variety of forms. This encompasses physiological indicators, including heart rate (Healey, 2014), pupil dilation (Partala and Surakka, 2003) and skin conductance, and speech and vocal communication (Cowie et al., 2001). Another indication of emotional state can be gathered from users providing their own assessment via self-reporting questionnaires (McNair, Lorr, and Droppleman, 1971; Watson, Clark, and Tellegen, 1988). This section reflects on previous research of these approaches, evaluating their potential use in the physical context of running.

2.2.1 Physiological Indicators

In section 2.1, the importance of the brain in processing emotions was discussed. Particularly the role the limbic system plays in sending signals to the body to activate changes in physiological activity (Oatley and Jenkins, 1996), such as muscle tension, skin conductivity, respiration, and heart rate. Multiple studies for detecting emotions have found success in using these physiological indicators, thus for this reason a few of these are explored below, assessing their possible applicability for the project.

Heart Rate

Whilst many physiological sensors have been used as indicators of emotional state; heart rate sensors are one of the most prominent. An elevated heart rate is reflected in an increased arousal of the nervous system, with a decreased heart rate expressing a depletion of nervous system activity as an individual returns to a more placid state (Healey, 2014). Studies by Palomba, Angrilli and Mini (1997), and Bradley and Lang (2000) have indicated that heart rate decreases in response to emotional stimuli, with increased deceleration when interacting with an unfavourable stimulus. Additional research conducted by Anttonen and Surakka (2005) extends these findings, highlighting that by evaluating the heart rate of an individual we can potentially distinguish differing responses to positive, neutral and negative stimuli. This is unalike to other physiological sensors that will be discussed later.

By capturing the acceleration and deceleration of a heart rate it is also possible to calculate the mean variation in comparison to a baseline, the durations of acceleration and deceleration periods and the associated magnitude of these, as noted by Healey (2014). In addition to this, the prominent usage of these sensors may be attributed to the fact that heart rate cannot be easily controlled by an individual; thus providing a propitious measure of the involuntary nature of emotions (Healey, 2014).

These sensors are however perceived to be obtrusive as they have to be attached to the body (Anttonen and Surakka, 2005). In particular, a test called an electrocardiogram, that is used to monitor the rhythm of the heart, requires that electrodes with wires are connected between a user and a sensor recording machine. Whilst a number of wireless technologies that integrate with mobile phone applications are now becoming available to collect this data, such as Quardio, they are yet to become prevalent for usage amongst everyday consumers. They also still potentially offer discomfort for wearers, particularly if engaging in physical activity, the premise of this project.

The largest challenge of using heart rate sensors is in identifying what reflects variations in emotional state as it is not the only factor that causes heart rate to change (Healey, 2014). One factor that is particularly influential is that of age. As individuals get older there is a diminished degree of heart rate change that is able to be detected. However, this is not of great concern for a study as this could be accounted for when choosing the pool of participants. Another consideration of user study participant selection would be an individual's current and previous level of fitness. A physically fit individual's heart rate is likely to be lower as the heart doesn't have to work as hard to pump oxygen round the body, thus making it more difficult to measure. The act of engaging in physical activity has been believed for many years to influence heart rate as well. However studies by Clarke et al. (2005) noted that no adjustments need to be made to real-time emotion inference systems to account for exercise.

The above discussion exposes a number of advantages that heart rate sensors provide as a tool for inferring emotions. For this reason, this method may be considered for use in relation to this project, but further investigation needs to be carried out to assess the viability of this within a running scenario. If implemented, it is likely to be used in conjunction with another indicator to validate the measurements. Self-reporting, which will be discussed later in this chapter, may be a suitable accompaniment.

Pupil Dilation

A form of physiological sensor that is deemed less obtrusive is that of eye tracking. This can be used to detect changes in pupil dilation, without the use of sensors directly attached to the body. Studies by Janisse (1974) and Partala and Surakka (2003) have shown that pupil size increases significantly in response to positive and negative emotional stimuli, particularly in comparison to stimuli deemed as emotionally neutral. However, it is difficult to make a distinction between experienced emotions being positive or negative as pupil size shows little variation between each. Notwithstanding, as pupillary response is a physiological response of the body, activated by the nerve system, it is difficult for an individual to fully control. Therefore, alike to heart rate, it is capable of highlighting impromptu behaviour (Baltaci and Gokcay, 2012).

Another disadvantage of using this method, however, is that it is vulnerable to the effects of the pupillary light reflex. This reflex controls the pupil size dependent on the light intensity it captures. If the intensity of light increases, the pupil's will decrease in size regardless of the presented stimulus, thus skewing potential indicators of emotional state. This will provide particular difficulty for the context of this project where user studies will be conducted outside, and lighting conditions are therefore unable to be manipulated. Although it may still be worthy of exploration in the context of running if a user runs on a treadmill in a room where the lights can be controlled to account for this.

As discussed earlier, eye tracking is deemed to be less obtrusive than heart rate sensors, but it still poses restrictions on a user. Despite current advancements in eye tracking technology, such as Tobii, some calibration to eye height is still required to enable obtainment of measurements. This would present difficulties in the physical context of this project where individuals will be constantly moving. The feeling of being continuously watched by this tracker highlights a further implication of this method. This could not only leave users feeling as though their privacy has been invaded but it has also been found that people act differently when they know they are being filmed (Zuboff, 1988).

Skin Conductance

Another physiological property of interest is that of Galvanic Skin Response (GSR). As the body prepares itself to deal with a perceived stimulus, thus arousing the nervous system, it increases its secretion of sweat to cool the body. The variance in the conductivity of the skin due to the sweat can therefore be measured at this time (Braithwaite et al., 2013; Healey, 2014). It is noted that the higher the arousal, the higher the measure of the skin conductivity. However, studies by Lang (1995) have found that GSR is only measurable in relation to the arousal of the individual, not their valence as well. Without the use of valence it presents a challenge in being able to uniquely identify emotional states, particularly those of a more complex nature. Self-reporting could be used for validation in this instance.

GSR is most famously known for its application in 'lie-detector' tests, which in recent times have been commercialised by companies and the media. During a test an individual's pulse, blood pressure, respiration, and GSR are monitored for variances in relation to specific questions that are asked. The GSR can be compared to a recorded baseline before the test to evaluate whether the individual is perceived to be telling the truth or not (Moore and Dua, 2004). Due to its commercialisation, GSR technology is inexpensive and relatively unobtrusive in its design in comparison to other measures of physiological responses. Data is usually collected via the attachment of electrodes to two adjacent fingers of participants. The reason for this is that the palms of hands and soles of the feet are where the sweat glands that respond to stimuli are concentrated (Healey, 2014).

As technology has advanced further exploratory research had been conducted into integrating skin conductivity sensors into clothing. Healey's e-textile sock (2011), whereby electrodes are attached to the sock and worn within a shoe, thus increasing the contact between sensors and skin and potentially leading to more accurate results, is of particular interest. It highlights the feasibility, and usability of this sensor in user studies of a more natural setting. However, it was found that data was unreliable when collected during standing and walking, so there would still need to be further investigation to understand if it could be applied within the physical setting of this project. Nonetheless, the general idea of integrating textiles and sensors is of significance as could help with the mobility of the project sensors required for the user studies.

A number of other issues, that are yet to be resolved, are also presented by the use of skin conductance as a response measure. Firstly, there are great differences of skin conductivity within individuals (Ward and Marsden, 2003), thus comparing data and drawing conclusions across user study participants could be relatively difficult. However, initial tests in selecting candidates could minimise the occurrence of this problem. The active context of the proposed user studies could also skew results, as participants will probably sweat generally due to the physical exertion. Whilst this could be minimised by keeping the exertion to a comfortable degree, the external factor of the outside temperature during the experiment will be unable to be controlled. On reflection, measuring GSR may be overly complicated for the implementation of this project, yet aspects of its flexibility with regards to integration with clothing are worth considering as part of the system design.

The analysis of potential physiological indicators presented in this section has disclosed concerns of impracticality of usage in a physical experiment setting and difficulty of accounting for external influencing factors during detection. Whilst there are advantages of their application it is unlikely that they will be able to be implemented without conflicting with the core goals of this project, namely that the indicator should place minimal constraints on a user's normal exercise posture and should feel natural for them to use and interact with.

2.2.2 Vocal Communication

Research on the instantaneous detection and categorisation of emotion from the vocal quality of speech has been of increasing interest in recent literature, but very few papers existed before the late 1990s (Schuller et al., 2011). As technology has advanced we have developed from only being able to detect what a user is saying, to distinguishing between users in a conversation, to present day studies of analysing how people speak and interact. These investigations of vocal communication are an attempt to understand whether they present any indication of an individual's emotional state (Cowie et al., 2001).

Studies within this field have discovered that pitch appears to be reflective of an arousal dimension (Gunes and Schuller, 2013). The mean value of an individual's pitch, rate of speech and the intensity also appear to be correlated (Cowie et al., 2001). An additional dimension of valence is similarly recognised by vocal features of rhythm and changes in note duration. For example, if an individual is angry or joyful they commonly speak faster and more intensely, with a greater variation in pitch. In contrast, a disinterested or upset individual usually exhibits slower vocals with more downward inflections (Brave and Nass, 2002).

Amongst emotional indicators speech recognition has been one the most prominent in undertaking research using rehearsed and artificially-generated data (Cowie et al., 2001). This presents limitations as emotions that are forcefully acted differ from those normally experienced by an individual (Batliner et al., 2011), and are less evident in associated physiological body responses. They are also restricted in that they usually only expose the most distinct emotions, with more subtle emotions, such as hesitation and empathy, being more likely to be identifiable in impromptu situations (Lutfi et al., 2013). The optimal set-up would be to continuously record users without their knowledge in a natural setting, as there may be some imposed anxiety at the thought of being monitored. This does however raise a number of privacy concerns (Schuller et al., 2011).

Recent research highlights that an increasing number of systems are beginning to be developed to recognise in-time impromptu speech. An example of this is a system developed by van der Wal and Kowalczyk (2013) that automatically measures fluctuations in emotional state during the natural dialogue of Dutch speakers. Whilst participants were aware of their voice being recorded they were not informed that the identification of emotions was the reason for this. In this project it is worth considering the approach taken to inform participants of the intended study, to ensure that their behaviour is not biased by disclosed details.

In spite of some successful studies, continuous speech still poses many challenges when evaluated, as there is a need to identify individual words to highlight the start and end times of emotional states (Gunes and Schuller, 2013). This then allows researchers to segment and categorise the individual emotions experienced. In addition, words can easily be distorted, and natural dialogue also includes filler words that often reflect inner thinking rather than a specific emotional state (Ward and Tsukahara, 2003). The contention of noise only adds to this issue. As alluded to earlier, constant recording and therefore processing is more indicative of a real-world setting, but also provides less detailed classifications (Schuller, Steidl and Batliner, 2009). Whilst several studies have attempted to address this, such as that by Lugger, Yang and Wokurek (2006), they aren’t tailored to individual vocal changes that may occur, or environments that are overly noisy. They appear to have had some success in stationary contexts, but as of yet they do not appear to be applicable in a physical setting. An additional question is whether a runner is able to speak continuously whilst running. Although this will be dependent on their fitness level and how challenging they perceive a given run, it is thought unlikely that an individual would be able to talk for a duration long enough for their emotional state to be inferred.

2.2.3 Self-Reporting

The indicators that have been explored up to this point have acquired considerable interest, and thus a multitude of research has been supported to examine them in different contexts. A form of indicator that has commonly been overlooked is that of self-reporting, with an individual directly interacting with a system. The lack of research into the application of this indicator in a HCI context comes as a surprise, as a number of complimentary scales and measures have been created and validated. Self-reporting also appears advantageous as provides the user with some control over their privacy; this may therefore be perceived as less invasive. However, questionnaires are only able to provide assessment of conscious features of emotion that the user wishes to share. This may highlight why investigations have focused on physiological indicators that reflect the unconscious emotional processing of an individual (Brave and Nass, 2002).

Self-reporting asks users to answer a number of questions, which can then be compared to measure distinct emotions or used to plot captured data on varying dimensions. These questions may be open-ended, such as “How are you feeling?”, or individuals may be provided with a set of emotions of which they have to note the intensity of that emotion that they currently feel. The former, qualitative approach produces data that is difficult to analysis so it is more commonly used for self-reflection rather than identifying distinct emotional states. The latter method, of providing a set of emotions, may impose restrictions on a user, as they may not identify with the words presented. For these reasons the validity of the questions presented and their applicability to the proposed study environment should be tested prior to the commencement of extensive user studies (Terry, Lane and Fogarty, 2003). Notwithstanding, users can find difficulty in expressing their emotions in words so a presented set could be seen to provide assistance in this scenario (Brave and Nass, 2002). Examples of self-reporting scales, such as McNair, Lorr, and Droppleman’s Profile of Mood States (1971), Watson, Clark, and Tellegen’s Positive and Negative Affect Schedule (1988), and Lang’s Self-Assessment Manikin (1980), will be discussed later.

A main consideration for this form of indicator is when to gather the data from the user. Post-interaction questionnaires are presented as the most popular method of finding emotion amongst the indicators explored (Brave and Nass, 2002). However, for the context of this project’s study in-action questionnaires would need to be used, which may interrupt the experience of the user. Breckler and Berman’s (1991) method of asking students to indicate their current emotional feeling (positive, negative or neutral) by pressing a choice of three buttons provides a practical and portable solution for consideration. A bracelet prototype proposed by Rodriguez et al. (2016), that is aimed at enabling aging adults to input complicated information regarding their emotional states and level of chronic pain, also shows similar promise.

Over the years multiple questionnaires have been developed and validated for the measurement of emotions. As expressed earlier, many of these present a user with a collection of emotional adjectives and ask them to rate how much that adjective currently describes their perceived emotional state. McNair, Lorr, and Droppleman’s (1971) Profile of Mood States (POMS) as an example, uses 65 adjectives, such as angry, hopeless, exhausted and energetic, that individuals rate on a five-point scale from 0 signifying they don’t feel that emotion at all to 4 corresponding to feeling the emotion intensely (Brave and Nass, 2002). These questions are useful as can be asked for differing time frames, for example “How are you feeling today?” or “How are you feeling right now?”. However, due to the volume of questions that POMS presents, and the associated inconvenience and obtrusiveness these afford in a study context, a number of condensed versions have been explored (McNair, Lorr, and Droppleman, 1992; Terry et al., 1999). If this measure is selected for use in this project these shortened versions will need to be investigated further, to assess their appropriateness for the user studies and the running setting.

Another popular method is the Positive And Negative Affect Schedule created by Watson, Clark, and Tellegen (1988). Positive emotion in this context is seen as the degree to which an individual is excited and energetic, whereas negative emotion is observed as emotional states of fear, nervousness and distress. An initial set of items were selected, partially from existing validated studies, and analysed before a subset of them, deemed as "relatively pure markers" of positive and negative emotion independently, were proposed for the scale. Understanding of variations in positive and negative emotions separately could be useful in the user studies, and has not seen to be provided by other indicators. The final list uses a mixture of ten positive and ten negative words, including interested, afraid, enthusiastic and irritable. Whilst not all of these terms would be applicable for use in the context of running, as they are limited in number it is imaginable that users could respond with relative ease if used at multiple intervals during a study.

A pictorial variation for rating on a scale is presented by Lang (1980) in the form of the Self-Assessment Manikin. This method asks subjects to rate the perceived arousal (intensity of felt emotion), valence (whether they feel positive or negative), and dominance (whether they feel in control) of their current emotional state by selecting the corresponding image from the dimensions, displayed on a five-point scale. This method is seen as preferable in comparison to speech and vocal indicators, as avoids the difficulties presented by attempting to account for cultural and linguistic differences (Cowie et al., 2001). Whilst running however, it may be difficult to distinguish between the manikins and their differing sizes.

In addition to the presentation of images, colour has also been used as a simple and easy representation of a set of emotional states from which users are requested to select. An application of this is MoodJam (Li, 2012), a website that encourages visitors to use squares of colour to symbolise their mood. Users are autonomous over their selection of what colours they choose to represent different moods, which provides limitations for cross-user comparisons and analysis if used within a study. In a practical setting further constraints are presented by requiring a user to select from a defined set of colours (referencing specific emotions), as it is likely that they will only be able to remember a small number of associations. Particularly when physically active during the study, they are unlikely to be able to make clear distinctions between the sets of different colours. It is therefore important if using self-reporting as an indicator that the input questions and selections are of a small subset, and that a user is aware of their meaning before the commencement of a study. This meaning needs to be further correlated amongst all of the users to enable comparisons to be drawn.

2.3 Modelling Emotions

In the previous section indicators of emotional state and the approaches taken to capture these was discussed. Presented with this data we then need to evaluate whether inferences can in fact be made of an individual's emotional state. Deciding upon how this data will be evaluated will provide the basis of a system that is then capable of providing a representation of an emotional state to a user for feedback.

A first consideration is the model of emotion to be used. Reflecting on the research discussed in section 2.1.2, investigations in previous literature (Brave and Nass, 2002; Oatley and Jenkins, 1996) present two differing approaches. The first is that of the basic emotions theory, where emotions are presented as a discrete set (Ekman, 1992; Kobayashi and Hara, 1997). The second is the componential theory which uses various emotional dimensions of a continuing scale (Liapis et al., 2015; Partala and Surakka, 2003; Sonderegger et al., 2016; Scherer, 2009).

As this project is aimed at investigating how to detect, infer and represent the emotional state of an individual across the duration of a run, the continuous dimension approach of the componential theory seems most appropriate. With factors other than emotion influencing many of the indicators researched, flexibility in the chosen model is required to account for these; the basic emotions theory does not provide this. The effect of the pupillary light reflex on pupil dilation discussed earlier is an example of one of these factors. The continuous quality of the chosen method reflects this project’s aim of dynamically representing a natural progression of an individual’s emotional state over time.

Having decided the model of emotion to be used, the emotional dimensions now need to be selected. A number of dimensions are presented in previous literature, with the most noteworthy being that of arousal (the level of intensity of the emotion), and valence (the degree to which the emotion is deemed to be positive or negative). A great array of work, by Liapis et al. (2015), Mou, Gunes and Patras (2016) and Povolny et al. (2016), already exists using the arousal-valence dimension space. However, whilst current physiological detection systems are able to measure the arousal dimension of incoming signals, many cannot detect the valence (Desmet, Vastenburg, and Romero, 2016). Therefore, if physiological indicators are used in this project the valence of the data will need to be verified with a self-reporting technique.

One of the oldest applications of dimensions, Lang’s Self-Assessment Manikin scale (1980), also proposes an additional dimension of dominance (the degree to which an individual feels in control). This scale is particularly popular, and has been used in a wide variety of studies (Bruun et al., 2016; Grimm and Kroschel, 2005; Hartanto et al., 2014). A more recent study by Fontaine et al. (2007) provides a further extension with the dimension of unpredictability.

Whilst it is possible that using all of these dimensions could provide additional information to represent an individual’s emotional state, they also add complications to implementation deemed beyond the time constraints of this project. As the main focus of this work is on assessing the impact a dynamic representation may have on a user, and the application of emotion inference in a physical context, only two dimensions will be incorporated. From the studies above it has been argued that the dimensions that best capture the fundamental characteristics for physical activity are arousal and valence, thus these will be used in the model of emotion within this project.

Prior to this section we explored the various concepts relating to emotion, how emotion can be consciously or unconsciously indicated by individuals, and the ways in which we might approach capturing these. This section has then concluded that a two-dimensional space of arousal and valence will be used to model emotion. The premise of this project is however grounded in how this inferred emotional state is dynamically represented to a user for their interpretation. Previous work within this field is discussed in the next section.

2.4 Representations of Emotions as User Feedback

The main exploration of this project is in finding a representation of an individual's emotional state that can be provided as feedback to a user. Whilst this has been studied in stationary settings, such as through the use of ambient lighting (Snyder et al., 2015), as discussed later, it has not been investigated in a physical context where further considerations need to be made for the portability of such a display. Research of possible representations of user state used in differing contexts are examined in this section, the features of which may provide design considerations for the project.

In recent years the computational representation of emotion has seen active research within emotional agents, with studies across multiple fields such as learning, health and video games (Beale and Creed, 2009; Pena, Peña and Ossowski, 2011). With these agents providing evidence of influencing an individual's emotional state they are particularly popular within teaching and mentoring applications (Sims, 2007). As noted by Bartneck (2003), they are also credited for their ability to provide users with "natural and continuous feedback". Though the meaning of natural is unclear, feedback must be adapted to the demands and circumstances of a user's activity. Many agents have been created to replicate the human form, thought to aid users in their interpretation of them (Perera, Kennedy and Pearce, 2008). An interesting example is that of Bickmore and Picard's (2005) development of a virtual exercise advisor called 'Laura'. Participants who were not engaging in the recommended level of exercise in the United States were selected to interact with 'Laura' daily to help improve their relationship with exercise. The system utilises a graphical embodiment of an agent that users can engage with in textual dialogue. 'Laura' displays a range of movements in body posture, hand positioning and facial expression to better communicate with users. In a stationary setting this could help to build rapport with users, however the subtleties of these gestures may be missed if the representation is trying to be interpreted whilst moving.

In addition, whilst the use of human faces has been found to be more engaging it is also noted that it takes more effort to interpret them, despite their familiarity (Koda and Maes, 1996). With the increase of social media interactions and the use of emoticons (emotion icons) to express emotional state, a number of more simplified expressions of the face could be appreciated by a user. This behaviour also indicates a preference for individuals wanting to symbolically represent their emotions rather than express them in text (Derks, Fischer and Nos, 2008). Okonkwo and Vassileva (2001) embodied this in their development of an emotional agent called 'Smiley', whereby six distinct emotional expressions were displayed upon a face. Similarly in Etcoff and Magee's studies (1992), unembellished computer-generated drawings of facial expressions were constructed and presented in sets that displayed one emotional state developing into another. The former of these approaches could present limitations if data captured reflects an emotion not represented by the six states, with the latter presenting the opposing issue of being too complex for correlation of collected data to a specific graphic. If used within this project a compromise between the two would need to be explored.

Representations of emotion have also made use of colour. A study by Snyder et al. (2015) represented biosensor data relating to an individual’s state of arousal through a lighting system. Tones of blue were used to represent a calm state, whereas a red state was reflective of a higher state of arousal. A further experiment using the system (Matthews et al., 2015) was conducted, whereby participants were instructed to change the lights from red to blue in the shortest time, but instead of the lights changing according to their biosensor data a pre-recorded light output was displayed. In this instance participants became relaxed more quickly than when presented with their true feedback. This highlights the influence that colour can have on mood if the mapping is understandable to users (Brave and Nass, 2002). However, as the system uses a set palette of colours to represent the emotions it does not account for individual associations of colour.

MoodJam (Li, 2012), as discussed earlier, is an alternative tool that allows a user to select their own colours. Whilst colour appears to provide a favourable representation of emotions the device it is represented on will need to be given careful consideration as in an outside setting external light may cause the colour interpreted to differ from what is represented. The positioning of the device in particular needs to be tested prior to full user studies.

The above discussion has highlighted a number of potential ideas that the form of the dynamic representation could take. These possibilities do however present challenges that will need to be further investigated through early engagement with users, to enable the creation of a usable system.

2.5 Summary

This literature survey has discussed the concepts that underpin emotion, before presenting physiological and vocal indicators of emotion, and self-reporting techniques (all section 2.2). How emotion may be modelled (section 2.3) was then explored, with further investigation of possible dynamic representation displays (section 2.4).

The first section cast doubt on the utility of leveraging emotional effects on the physiological responses of the body (Oatley and Jenkins, 1996). The basic emotions and the componential theory (Brave and Nass, 2002; Oatley and Jenkins, 1996), the two most popular theories of emotion, were then critiqued before deciding on the concept of emotion as lasting only a few seconds or minutes, but influenced by the longer durations of mood and sentiment. The impact of the residue of previous emotional states, known as excitation transfer (Zillmann, 1991), was further recorded as a valid consideration.

The review then looked to the physiological and vocal indicators of emotion that an individual might display, and what mechanisms could be used to detect these. Self-reporting techniques, placing a user in control of providing emotional data, were discussed as a viable form of indicator with minimal intrusion concerns. However, it may be noted that there would be challenges in adapting this approach to provide continuous data. A particular focus during this discussion was whether the mechanisms could be used in the active setting of the intended experiment. For this reason the obtrusive nature of devices was also considered. To gain a better understanding of the applicability of these tools to a running context further investigation is required, after which decisions for the exact combination of mechanisms that will be used will be finalised.

The next section explored how the collected data might be used to model emotional states. The componential theory (Brave and Nass, 2002; Oatley and Jenkins, 1996) and its support for continuous dimensions, discussed in section 2.1.2, was seen to offer required flexibility and thus was selected. The chosen dimensions to model emotion are that of arousal and valence, as they were seen to provide simplicity whilst drawing upon the key features of emotion, and allowing a greater focus of the project on the representation to the user.

In conclusion, there is currently limited research within this area but some potential ideas to be considered for use in this project's representation. Of particular interest was the use of light, and the experiments conducted with a system called MoodLight by Snyder et al. (2015). There are noted challenges about how these representations could apply to the given environment of the proposed studies, thus it was acknowledged that early engagement of users in design prototypes would be important. The next chapter will examine the potential for self-reporting at regular intervals during physical activity in a real-world setting.

Chapter 3

Initial User Study of Runners in the Wild

This chapter reports a field study of runner emotions. The main aim of this chapter is to explore further the interaction between emotions and exercise, specifically running, to enable the design of a system that could detect and represent an individual's emotional state within an active environment.

A key driver for this study was the lack of research into how systems can understand and represent emotions during physical activity; with many studies within the area of Sports Science solely focused on investigating physiological changes displayed by the body.

A second motivation for the study was to observe in detail runners engaging in the activity, rather than basing analysis on the information provided by participants in a restrictive interview setting. The trial also enabled the author to further consider the practical challenges a built system may pose, and how features of a system could be designed to overcome these and allow interaction with users that is not deemed too obtrusive or invasive to the user and the intended session task. For this reason, the accessories used by participants whilst running were also noted. When a prototype of the system is created, later in the project, it will be important to engage users again to provide their feedback on its usability before full user studies commence.

In this study data was collected through questionnaires conducted 'pre-run', a 'during-run' interview with frequent questioning about user emotional state, and a shorter questionnaire conducted 'post-run'. These questions focused on evaluating the running history and habits of the participants, also noting feelings they experience in relation to and whilst running. An inductive approach to analyse the qualitative data was taken, with the author iteratively reflecting on and comparing the dataset to code and collate common themes that could provide key design considerations absent from the more generic conclusions presented by the literature review. By analysing collected data we also looked to create specific research questions, to be investigated through the following project phases (see section 3.3).

Due to the success of the initial field study the main user study, presented in Chapter 6, followed a similar approach and presented many of the same questions to users. For this reason, the following subsection discusses in greater detail the study design, providing rationale for the questions posed to participants.

3.1 Study Design

In order to test the practicalities of this study and provide some validation of the study concept an initial pilot was conducted with two participants. These participants were recruited via e-mail and asked to answer a number of questions 'pre-run', 'during-run', and 'post-run'. With the possibility of a user being distracted whilst providing data during a run, potentially resulting in an accident, it was decided that the author would run alongside a participant collecting data on their behalf. These participants were sent a written brief found in Appendix A.1.1, prior to the day of their session, providing an overview of the context of the study in relation to this project. This form also requested consent for partaking and acceptance of the associated risks of engaging in physical activity. This brief was presented again on the day of the sessions prior to them commencing. Participants were also presented with the option of viewing their captured data on completion of their individual session, and welcomed to provide their e-mail address if they were able and wished to participate in future studies of the project with the implemented system. This study was designed to take into account ethical considerations as codified by the ethics checklist provided by the Computer Science department.

Upon completion of the preliminary pilot the question sets and experiment were further refined, reflecting participant feedback. The intervals between asking how participants felt for the 'during-run' interview were extended from 30 to 40 seconds to allow enough time for the question to be asked and responses recorded accurately. As a result, the distance undertaken during the sessions was also increased, from 1 mile to 1.5 miles, to ensure a similar number of responses could be captured. It was decided that increasing beyond this distance could tire both the participant and the author whilst not yielding any additional insights. The pilot also highlighted that some responses to questions were rather short, thus going forward participants will be asked to expand on their responses and provide supporting examples where possible.

A user study of five runner participants was then conducted. Alike to the pilot, participants were recruited via e-mail, and additionally via social media. The participants were asked to partake in a 'pre-run' questionnaire of 35 questions, a 'during-run' interview with data transcribed into a mobile device at approximately 40 second intervals, and a 'post-run' questionnaire consisting of four questions. The ethics checklist was also adapted to reflect the changes made. The completed form can be found in Appendix A.1.2.

As noted above, each session consisted of three distinct parts. These are discussed in detail in the next three subsections.

Part One: 'Pre-Run' Questionnaire

The first part of each session, a 'pre-run' questionnaire, intended to reveal a broader understanding of the problem domain. It explored each participant's commitment to running and other exercise they engage in, specific details of runs they had been on, equipment and accessories they use, and their sentiment towards running. A subset of these questions were subsequently adapted and used in the running habits questionnaire of the main user study (see Appendix B.1.2).

The last set of questions in this initial questionnaire were presented immediately before the 'during-run' interview was conducted, in an attempt to capture the participant's mood and emotional state prior to engaging in exercise. This data was later used for comparison with 'post-run' information. Whilst the same core questions were asked to all participants, they acted as more of a script with additional examples and prompts given as necessary, to further explain concepts and uncover additional information.

Due to the different sets of data this questionnaire aimed to capture, it was split into multiple sections. These sections are briefly discussed below in conjunction with the related questions posed:

History

Participants were initially asked what age bracket they were within. This information was used for comparison between participants to understand whether there were differences in data across age groups, with more mature participants potentially having more running experience. Whilst this data could be considered of a personal nature it was not recorded against an individual's name and participants were informed that they did not have to disclose this information.

Statistics

The running habits of participants were also questioned, including how many times a week they run, the mileage undertaken and average pace. Analysing this data could begin to build a profile of a runner to understand how much they would benefit from using the system this project intends to implement. The average pace was of particular importance so the author could assess whether they could comfortably match this and thus conduct part two of the user study alongside the participant.

Other Exercise

Exercise aside from running that the participant engaged in was also captured. This again reflects to what extent exercise is part of the participant's lifestyle and how physically fit they are. It was assumed that those undertaking additional exercise may find running easier, thus providing differing results to participants who only run.

Feelings and Challenges

This section of the questionnaire was of key importance for the study, aiming to understand why people run and therefore the factors that contribute to running becoming a habit. Exploring how participants feel about running was intended to give rise to specific considerations for the design. For example, if a number of participants noted that they feel nervous about running then 'nervousness' could be considered as an input word if using self-reporting for the implemented system.

Participants were also asked in this section:

- Is there anything you find particularly difficult when preparing for a run?
- Is there anything you find particularly difficult when running?

The difficulties and challenges faced will be considered, with the implemented system adjusted to try and support these.

Equipment and Accessories

With the increase in consumer technology in the fitness industry (Allen and Christie, 2016), a large number of runners own and use some form of device or mobile application that tracks fitness statistics, such as pace, heart rate and distance. This section aimed to investigate what equipment is currently being used, the particular statistics that are tracked, whether a user tracks these during and/or post-run, and how this information is displayed. As participants use this equipment it appears to imply that they do not deem them overly obtrusive, thus features of these should be considered for inclusion in the system implemented for this project. The fitness statistics noted also highlight potential data that could be captured during future studies that may provide additional inferences of emotional state. Non-technical equipment, such as water bottles and running belts, was also recorded to distinguish what a participant carries with them during a run and how they carry this, thus providing insight on how the implemented system could be carried.

Types of Run

A few short questions were asked to determine the types of run a participant usually undertakes. As the questionnaire was asked in person further explanation of these types was provided. This was necessary as the definition of run types differs across the running community. This information will be used to construct the routes taken for future user studies.

Previous Runs

As discussed in the literature survey, sentiment has a great influence on an individual's emotions. As such, it was seen important to understand a participant's sentiment towards running and how they have reflected on previous runs. Of particular interest was what emotions were experienced as a result of previously missing a run, and whether these were of enough significance that a participant remembered them.

Pre-Run

Immediately prior to the second part of the session participants were asked about their current mood and emotional state, whether they felt prepared for the run and their current sentiment towards the run. These questions were also used prior to the runs undertaken in the main user study (see Appendix B.1.3 and B.1.4). An identical set of questions were asked 'post-run' so data could be compared.

Part Two: 'During-Run' Interview

The second part of the session was intended to examine user experience from the point of view of a runner engaging in physical activity in a naturalistic setting. It consisted of a 1.5 mile flat run with the author running alongside and interviewing the participant. The distance was chosen to ensure that a suitable number of responses could be captured but not causing the participant and author to tire, and potentially affect the results. For this reason, routes that were mainly flat were also selected.

As a participant was running along the author asked the same question, "How are you feeling?", at approximately 40 second intervals; intending to capture an average of 20 records per user session. This question was aimed at examining what people were feeling and thinking about during a run to understand what data could be collected to infer emotional states, and what system and associated set-up could assist in capturing this input.

The author transcribed what the participants spoke aloud in answer to the question directly into the questionnaire on their mobile device as they ran. The author felt that capturing the data in this form would result in the participant providing terser and potentially more honest answers than those that could be captured by audio recording, where a user could feel a necessity to expand and discuss their responses. Issues of misinterpretation and lack of clarity using audio whilst running also influenced this decision. The responses recorded were checked for accuracy with the participant upon completion of the run.

Part Three: 'Post-Run' Questionnaire

The last part of the session consisted of a short 'post-run' questionnaire:

- How do you feel right now?
- How do you feel about the run?
- Were there any particularly memorable moments on the run?

As noted above, these questions are the same as those asked prior to the run. These questions were also asked to participants during the main user study (see Appendix B.1.5). These were aimed at capturing a participant's sentiment towards the run, and understanding if their mood had changed as a result of the exercise endured. The questions were asked immediately after the session to ensure the participant could remember their 'post-run' state. An additional question was asked to note any significant events participants noticed on the run.

Due to the nature of the questions being asked throughout the user study it was felt that they could be misunderstood if a participant attempted to answer them by themselves online, and records could easily be falsified 'during-run'. For this reason the author asked the participants the questions in person, providing additional information and prompts where needed. As the collection of questions was constructed it was considered that a smaller subset may be presented, however as all of the questions were deemed important to the exploration of this study they were all asked to the participants. With the small number of participants recruited the length of the sessions was appropriate.

3.2 Results and Analysis

As noted in the previous subsection, five runner participants completed the initial study. This subsection presents the gathered information and the derived insights for all three parts of the study. Particular reference is made to how these findings can be incorporated into the design of the system being created for this project.

3.2.1 Profiling Runner Engagement

In the first part of the study the physical activity undertaken by individuals was recorded. This captured both the number of runs an individual undertook on average each week, and the average distance they covered on each of these. Other exercise they undertook was also noted, with the associated duration of these exercise 'sessions'. This information is used in some of the analysis presented below to identify any correlations in the data to an individual's overall engagement in physical activity.

Habits

Across the whole dataset participants on average ran three times a week, with each run an average of 3.5 miles. Individuals also engaged in an average of three other exercise sessions aside from running, including pole fitness, home workouts and gardening. The average duration of these sessions was 1 hour 10 minutes, resulting in most individuals undertaking approximately 5 hours 10 minutes of physical activity every week. The fairly active lifestyles of the participants in this dataset may have provided some biases to the collected and analysed data.

Reflecting on Individual Runs

As part of the 'pre-run' questionnaire participants were also asked to reflect on the last run that they undertook to enable the author to understand if this had any correlation with their run for the session. 60% of participants viewed their past run negatively, mainly due to the physical tire that they experienced. With participants asked to comment on their session run immediately upon completion, no mention of their physical state was made. Thus, to enable more accurate capture of an individual's running experiences future studies should include later follow up questions, a week or so after the session, to understand whether participants have changed their viewpoint of their run, having had time to further reflect and compare to previous runs and realise any physical impacts. This concurs with the concept of secondary appraisal, the conscious reflection on emotions experienced, in the work of Oatley and Johnson-Laird (2014). As a primary objective of this project is to create a tool that helps to encourage runners to reflect on their emotions during a run with the intention of that resulting in more positive running experiences, and providing motivation to keep running, an accurate understanding of how runs are perceived both emotionally and physically is essential. To fully understand the influence the system has had on an individual's running experiences and motivation, participants would need to participate in numerous runs over a number of subsequent weeks for comparison. Due to the limited time constraints of this project it is unlikely that more than two runs per participant will be able to be recorded and followed up on.

Barriers

Of particular interest in the initial questionnaire was the data captured regarding the barriers individuals faced in undertaking a run, and the challenges experienced whilst running. The effect of weather conditions was noted as the most prominent factor in individuals choosing not to run. Therefore careful consideration needs to be given to the conditions under which the final user studies for this project are conducted. If different participants are exposed to great variations in weather, and as a result interact with the system differently, this could skew the data collected. This was demonstrated in one of the user sessions of this study; one of the participants ran when it was very cold, resulting in a lot of their commentary during the run focusing on their physical feelings rather than emotional. For future studies contingency session dates should be factored into the project plan so that sessions may be rearranged if it is believed that the weather may affect the results collected.

During a run pacing, ensuring a consistent and appropriate speed, was considered a significant difficulty. Whilst it would be of interest to understand whether the variations in an individual’s pace correlate with their emotions, this is deemed beyond the scope of this project.

Running Routes

Additional questions of “What runs do you typically do?” and “What type of route do you typically take?” were also posed to participants to guide route planning for future studies. Many of the routes selected for the initial study were slightly disrupted due to traffic, with comments collected referencing this frustration. Therefore it is seen as preferable to plot a more rural route going forwards. The majority of participants noted undertaking circular routes in their usual running schedule so this should also be reflected in the chosen route. Overall, to enable better comparisons a single route should be taken by all participants. Whilst flat routes, where there is minimised challenge, appear to be favourable an additional test could be carried out to compare information collected from flat runs to that of routes that include hills, where the system may be needed for more support.

Physical Constraints of the Setting

The project also places constraints on the design of the system due to the physical setting in which the studies are to be conducted. The equipment that participants typically use whilst running was therefore recorded to understand what form the proposed system could take to enable it to be unobtrusive and natural in application, alike to other items the individuals use. 80% of participants carry phones on most of their runs, mainly for entertainment purposes, placing them in belts, armbands, holding them or putting them in slim-line rucksacks. This suggests that the creation of a moderately bulky system would not greatly impede a user, although a smaller and more minimalist design would be preferable. 80% of participants also use watches or fitness trackers, with 60% actively tracking statistics on their devices as they run. Creating a system that can be worn or placed on or near the wrist is therefore of great consideration, as users will already be used to looking towards the area for interval updates.

In addition, all participants used wired headphones, suggesting that hanging wires should not be considered as an issue during the design. On longer runs people noted that they carried a water or sports drink bottle; this provides a further consideration that the system could take the form of a device held by the runner. The collected data also revealed participant's use of audio updates provided by devices worn, including notifications on speed, distance and time. On carried mobile phones applications recited chosen statistics, with watches beeping to alert users to look at the watch display. As this is already an effective technique used during runs it could be useful to implement a similar tool in the proposed system to alert users to the intervals at which they should provide information to the system.

3.2.2 Contrasting Questionnaire Data

Following this, participants were asked prior to and upon completion of the run section of the study session "How are you feeling right now?". The repetition of this question was designed to consolidate the author's hypothesis that an individual would feel more positive 'post-run'. This theory was validated by the results with 60% feeling negative before the run, and 100% feeling positive upon completion. This is of interest as highlights the positive impact that exercise can have on an individual, thus affirming the necessity of a system that supports an individual to understand clearer their feelings during running to help establish better running habits and seek this benefit.

An individual's attitude towards running was also noted before and after the run for comparative measures. Little variation was found, with only one individual feeling more positive about the run itself after finishing. Whilst those who exercised and ran more appeared to view running more negatively, this could be due, in reflection of their comments, to a more competitive attitude to exercise being undertaken, and a greater expectation of personal performance. The last time participants had run, their average running pace, and their furthest running distance surprisingly seemed to have no notable impact on their sentiment towards running. 60% of participants initially had a negative attitude towards undertaking the run, supported by evidence that they sometimes face challenges in motivating themselves to start a workout. The system for this project is not intended to directly provide motivation prior to a run, but instead give encouragement during runs to change people's views on running and thus engage in it more.

3.2.3 Descriptors of Affect During a Run

For the next part of the study participants undertook a run, whereby they were asked at approximately 40 second intervals to comment on how they were feeling, speaking aloud the first word, thought or phrase that came to mind. The collected data consisted of a combination of items that were categorised as emotional feelings, such as happy and nervous, physical feelings, such as being thirsty and experiencing minor aches, and general moments that happened during the run, including interacting with passers-by and recognising places en-route.

Following the completion of the study noted items were further segmented as either positive or negative, with percentages of each group calculated for each session and overall. A few entries were excluded from the data set for analysis as did not appear to clearly identify with either category nor provide any additional insight. The results are presented in Table 3.1, with percentages presented to two significant figures.

Participant Number	Positive Items	Negative Items	% Positive	Number of Items
1	7	11	39	18
2	9	9	50	18
3	14	3	82	17
4	15	8	65	23
5	14	5	74	19
Total	59	36	62	95

Table 3.1: Results of Initial User Study – Positive and Negative Items

This table highlights that overall more of the communicated phrases were positive (62%), evident in three out of the five sessions. This concurs with work by Watson and Clark, (1999), where research for the PANAS-X scale discovered that participants reported more positive affective terms than negative. The age of the participants did not appear to have an impact on the ratio of positive and negative items, however only one active older adult was interviewed so this may not be an accurate representation of the group. Those participants who engaged in more exercise, including running and other activities, gave fewer positive responses. The author believes this could be due to running not being the participant's exercise of interest.

From the responses gathered it also appears that those participants that were more physically fit felt a necessity to push themselves more throughout the run, resulting in frustration and negative feelings if they felt they were not performing according to their own set expectations. These participants additionally expressed the most negative items towards the end of the run which could be indicative of the individuals reflecting on and realising their unmet goals. The system created for this project could help in this situation by encouraging participants to reflect and improve on their feelings during the first half of the run as well, which in turn could positively impact the latter half, resulting in a more positive experience overall.

The results were also considered in relation to the feelings towards a previous run, but no correlation was found. Nonetheless, a negative experience may sometimes deter individuals from undertaking another run unless motivated by a goal, such as training for a race or wishing to keep fit. The longest distance that participants had previously ran did however appear to be of note, with those having ran further indicating more positive items. Due to the minimal distance undertaken during the sessions, 1.5 miles, these participants could have found the run to be relatively easy in comparison to their normal mileage. In future studies it may be worth considering using runners who cover less mileage, or are generally less experienced runners, that may gain more benefit from interacting with the proposed system for the project.

After this initial analysis was undertaken a spider diagram was constructed to further organise and understand the data set from which insights could be drawn. This diagram can be found in Appendix A.1.3. A subset of the diagram, focusing on the categorisation of positive and negative items, is shown in Figure 3.1.

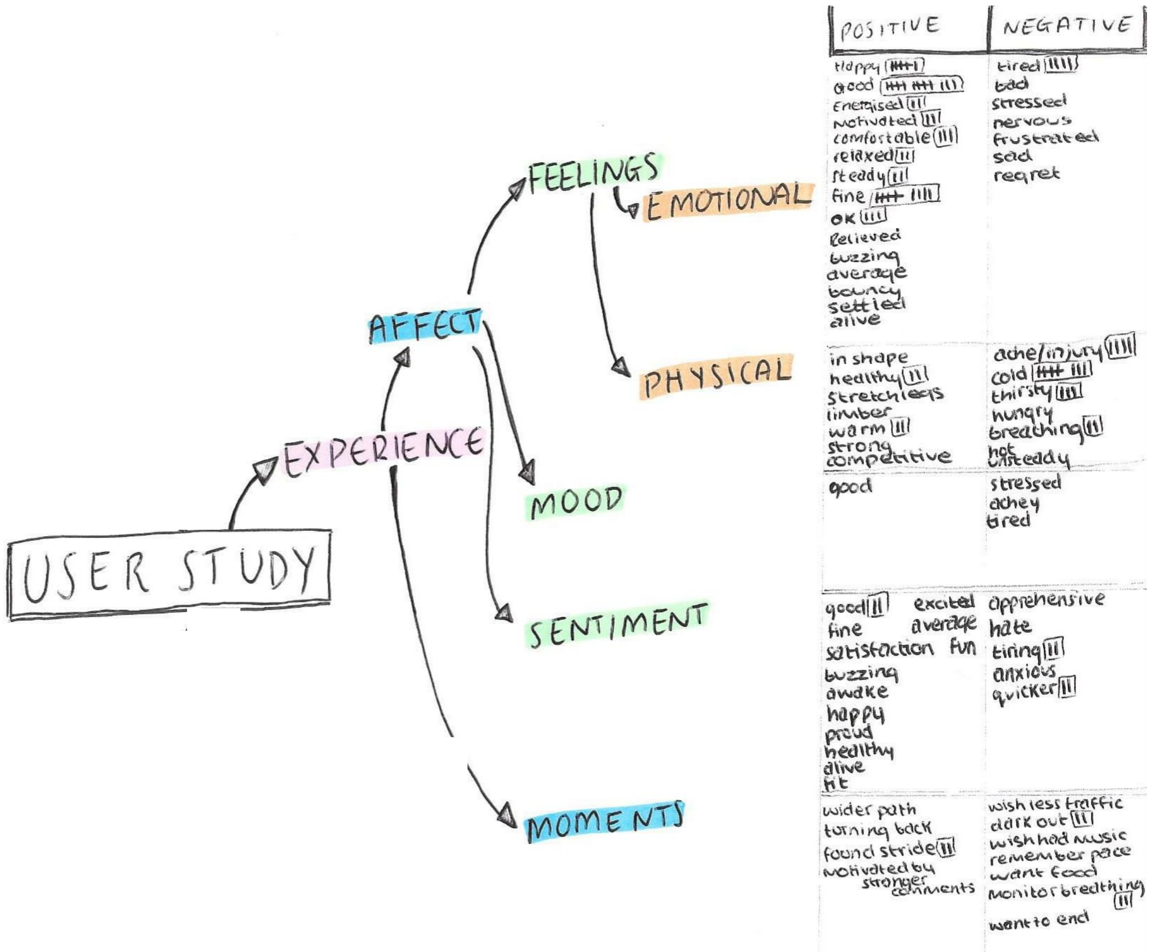

Figure 3.1: Spider Diagram of Initial User Study Analysis

As the dataset collected during part two of the sessions allowed participants to express what first came to their mind it consisted of a vast range of comments. Data collected in parts one and three of the study, in relation to how participants were generally feeling and their feelings towards running, also expressed great variation. For this reason the dataset of all sessions was collectively analysed using thematic analysis, whereby the collective of raw inputs were compared to identify patterns and organise the data set to help highlight discoveries of interest (Braun and Clarke, 2006). The full set of data captured for each participant can be found in Appendix C.1.1.

The data items captured were considered in relation to their longevity, reflecting upon the interpretation of these terms from the earlier literature survey (see Chapter 2). Those recorded at approximately 40 second intervals 'during-the-run' were noted as feelings, and the general feelings collected prior to and 'post-run' were noted as indicating an individual's mood. The collected comments relating to feelings towards running, again captured before and 'post-run' and also in relation to how individuals felt running generally made them feel, were catalogued under the heading of 'sentiment'.

The items captured 'during-the-run' were further categorised as moments, general comments or observations individuals made about themselves or their environment, or feelings. Moments tended to be expressed as phrases, longer in length than the often singular words that appeared to indicate feelings. The feelings were then additionally separated into emotional feelings, that appeared to reflect an internal state of being, and physical feelings, relating to how a participant felt their body was reacting to the exercise undertaken. Words or phrases that were repeated within individual sessions or across the study were also recorded, indicated by the tallies on the diagram. A few of the words and phrases were collected under a singular term where the author perceived the meaning was very similar.

Using the data across the whole study an adjusted version of Table 3.1, with some additional calculations, may be found below:

	Distinct Positive Items	**Distinct Negative Items**	**Total Distinct Items**	**Total Positive Items**	**Total Negative Items**	**Total Items**	**% Positive**	**% Overall**
Feelings	22	14	36	57	30	87	66	41
Emotional	15	7	22	48	10	58	83	27
Physical	7	7	14	9	20	29	31	14
Mood	1	3	4	1	3	4	33	2
Sentiment	13	5	18	14	7	21	67	10
Moments	4	7	11	5	9	14	36	7
Total	62	43	105	134	79	213	63	

Table 3.2: Results of Initial User Study – Distinct and Total Items

In reference to the table, the 'Distinct Items' columns refer to the number of individual words or phrases found in the dataset, with the 'Total Items' columns including the frequency of these words that was recorded.

Emotional Language in Running

The majority of the words spoken by participants were categorised as 'feelings' (40.8%). This is likely to be due to the nature of the sessions, with data being recorded at short intervals and in relation to how individuals felt 'in-the-moment'. Within the dataset 36 distinct 'feeling' words were found. Although this set could potentially have been further condensed, without the collated terms losing meaning, the author felt it was important to highlight the breadth of the words used. It also highlights how words that appear similar may in fact be difficult to group under a clear collective term. Of particular interest is the high percentage (83%) of positive items in the 'emotional feelings' sub-category. This provides indication that individuals felt generally positive throughout their runs, with the physical impact of running affecting an individual to a higher degree. Therefore including both physical and emotional words in a self-reporting mechanism would be necessary to accurately capture feelings 'during-run'.

A further consideration may be the weightings that an individual wishes to place on their physical and emotional feelings contributing to their overall state. Some runners may struggle more with their mind-set whilst running, rather than their physical capability. As such some form of user-selected weighting incorporated into the design of the system may be beneficial. This is discussed in more detail in the design chapter.

The most common positive ‘emotional feeling’ words used were happy, good and fine, which could be viewed as being differing states of arousal on a happy to unhappy scale. This is of great consideration for the design aspect of this project. The recorded word ‘comfortable’ was also of note as suggests potential for using an additional dimension of dominance, relating to how in control an individual feels whilst running, in the affective model of the system. Whilst ‘tired’ was noted the most frequent negative ‘emotional feeling’, it is acknowledged that this could also be perceived as a ‘physical feeling’. The author categorised it in this way as felt that being tired is often a mind-set held by runners rather than relating to physical tiredness; in these instances participants seemed to specifically communicate particular aches or pains. The ‘physical feelings’ appeared to present greater variety with feelings of thirst, being warm or cold, aching or generally feeling healthy.

Mood

Reflecting on the limited number of moods captured, it is difficult to draw clear conclusions. Nonetheless most participants were initially in a negative mood, due to other factors in their daily lives, prior to the beginning of the run section of the sessions. The use of the proposed system of this project will assist individuals in a negative state to easily record any movement towards a more positive state. The author anticipates that running in general is a mood enhancer. If individuals are initially in a positive state it may be more difficult to gage distinct changes, as they will be more likely to record higher levels of positivity from the start, thus operating in a limited range. For example, if an individual rates their level of happiness as 3 out of 5 at the beginning of the run (with 1 being not very happy, and 5 being extremely happy) then to improve upon their initial state changes will only be realised with recordings of 4 or 5, rather than 2, 3, 4 or 5 if an individual was initially in a negative state. Thus, the created system will need to be able to be adapted to a user’s mood to allow the full scale to be used.

Sentiment

Another interesting point that emerged was that people generally feel positive towards running. The aim of this project is to further increase this percentage, with the hope that this will encourage individuals to engage in running more frequently. Additionally, whilst only a small number of moments were documented, the majority of these (64%) were negative. This could be somewhat effected by the route selected for the runs, where participants passed multiple sites of interest and on occasion members of the public caused obstructions. If different routes are selected, particularly more rural as noted previously, this could impact on the results.

The Phases of a Run

Analysis was also conducted to understand the distribution of positive and negative items across the duration of a run. For this reason the run was split into three separate sections – beginning, middle and end. The items recorded during each individual participant’s run were then approximately split between these sections. For example, an individual where 18 items were recorded resulted in all three sections being allocated six items. If an individual data set did not divide evenly the additional items were noted within the data of the middle and end sections of the run. The number of positive and negative items for each section for each individual dataset was then recorded. Table 3.3 provides an overview of these calculations, with percentages presented to two significant figures. Positive items and negative items are stated under the column headers of *'P'* and *'N'* respectively.

Participant Number	**Beginning of the run**		**Middle of the run**		**End of the run**		**% Positive** *Beginning*	**% Positive** *Middle*	**% Positive** *End*
	P	*N*	*P*	*N*	*P*	*N*			
1	2	4	4	3	1	5	33	67	17
2	3	3	3	3	3	3	50	50	50
3	5	0	5	1	4	2	100	83	67
4	3	4	6	2	6	2	43	75	75
5	3	3	5	2	6	0	50	71	100
Total	16	14	23	10	20	12	53	70	63

Table 3.3: Results of Initial User Study – Run Segment Analysis

The majority of participants recorded more negative items during the beginning phase of the run. This data is to be expected as participants begin to warm up and adapt their running to meet their expected pace, strides and breathing patterns. In alignment with this, most individuals recorded a large increase in positive items in the middle of the run. For half the participants this positive outlook remained or increased into the end section of the run. The other half of runners experienced a decrease in positive items, which may be related to physical or mental tiring across the run and residue emotions from potential frustrations during the beginning and middle sections. Supporting this hypothesis; participants four and five who ran the slowest out of the dataset noted an increasingly positive experience over the run. Those who had most negative items in the end phase of the run (participants one, two and three) also noted more negative feelings towards the run after its completion, indicating frustration with their pace and the limited duration of the run, as they were used to longer distances. The participant that experienced the biggest positive increase in item ratios was the oldest of the individuals (participant five). This could be due to their greater amount of runner experience over the years and recent participation in long distance races.

Collectively, these insights have helped the author to better understand how individuals experience different emotions or moments during different run segments. This knowledge could be incorporated into the system of the project so that it adapts to the changing mind-set of an individual. Participants may also wish to view this data 'post-run' for more detailed analysis of their changing emotional state.

Conclusions

In conclusion, the analysis of collected data has provided many considerations for the set-up of future studies, particularly with regards to route and participant selection where it was found that external influencing factors could have been better controlled. The constraints placed on the design of the system to be implemented were additionally examined, with several potential design criteria noted. Further exploration of how the proposed system will interact naturally with users in the physical environment will be explored using storyboards and low fidelity prototypes in the design chapter.

One of the greatest benefits of the study, however, was the testing of a self-reporting mechanism, with the author successfully recording data running alongside participants. Whilst some small issues occurred during this initial study, they were iteratively improved upon with each session. These improvements, such as lengthened time intervals, can now be incorporated into the design of the project's system. Furthermore, the words used by participants during the run section of the sessions provide potential for being used as part of a self-reporting mechanism for the system. The validation of selected words will be discussed in greater detail later.

Overall, the analysis of the initial field study has helped to consolidate the author's understanding of emotions and exercise, enabling a clearer project scope to be defined. As a result a number of research questions may now be raised.

3.3 Research Questions

Having conducted and reflected upon the initial field study, it is now possible to note multiple research questions which the following phases of the project will focus on and aim to provide insight to:

Research Question 1: How could a user's emotional state be dynamically represented, for user interpretation, in an active setting?

Research Question 2: How could we collect data input from users in a non-obtrusive and non-invasive way, in an active setting?

Research Question 3: How might we use collected data to make inferences of a user's emotional state within a two-dimensional space of valence and arousal?

Research Question 4: Are users affected by emotional state representations displayed 'during-run'?

Research Question 5: Do users view a run more positively 'post-run' as a result of being exposed to representations of their emotional state?

The first and second questions provide the main challenges for the implementation of a supporting system. The active setting in which the system must operate places numerous restrictions on the design, with particular consideration needed to ensure that the device can be carried easily, and does not distract the user from their given task of running. If the device is to be viewed as a useful tool it must be able to be integrated as seamlessly as possible into the running process. To further enable successful adoption the cost of production also needs to be minimal, thus enabling the system to be able to be easily reproduced and available to end users. Moreover, the calibration of the system to individual users must be minimised so that it is quick and simple to use.

For research question two the data collected needs to be suitable for valid inferences to be made. With the recorded data we will then need to look at how this could be interpreted and expressed as differing emotional states, reflecting research question three. To enable users to better distinguish between different states, the full two-dimensional space of valence and arousal should be used.

The fourth and fifth questions then form the primary focus of the research efforts of this project; understanding the impact that the viewing of personal emotional states has on a user's actions 'during-run', and sentiment towards running 'post-run'. Comparisons will be made of system usage with and without the emotional state representation visible. Gathering data for participant's sentiment towards running may be slightly restricted due to the time constraints of the project.

With the consolidation of these questions, as well as the detailed review of the initial user study, we can now proceed to the design of the system.

Chapter 4

Design

This chapter aims to design a system capable of capturing, inferring and representing a user's emotional state in a naturalistic setting, drawing upon previous approaches discussed in the literature review, and insights uncovered in the field study of Chapter 3. Designing a system with multiple interacting parts is a complex task, thus this section takes a top-down approach, identifying a high-level overview before further examining detailed aspects. Initially the process of running is visualised through a storyboard, before the core system requirements are specified. An architectural view of the system is then presented, with exploration of individual subcomponents. A particular focus is placed on the user interface design, with the difficulties of the physical environment in which the device is to be used noted.

4.1 Storyboard

Whilst some design aspects of the system were briefly researched and discussed in the literature survey, no decisions of selection were finalised. A first attempt at visualising how a user may interact with the system was therefore constructed, as shown in Figure 4.1, drawing directly on the experiential data collected in the field study (see Chapter 3).

Figure 4.1: Storyboard of Running Process and User Interaction with the System

This storyboard also shows the questions and thoughts that a user may have at different points during the running process. The proposed system will aim to capture these thoughts to enable inferences of emotional state to be made.

The running process starts before a user commences running, in the preceding days and the build-up preparation. The user begins to think about how they feel in themselves and also their feelings towards the run they are intending to undertake. Following the procedure of the initial field study (see section 3.1), it was anticipated that this data would be captured via a short questionnaire. Comparative representations for individuals could reflect differing initial attitudes and emotional states for different running experiences. It is likely that a participant will use their starting emotional state as a baseline for following emotional recordings.

Upon completion of the first questionnaire, the user would then begin an interactive session with the system and start running. After a pre-defined constant time interval a light or noise would alert the user to begin entering their emotional data input. This design is reflective of the design features of accessories currently used by runners, as described in section 3.2.1. In the first instance, this communication would act as a cue for a user to think about how they are currently feeling prior to recording their thoughts. Whether this alert takes the form of a light or audio output may be dependent on the restrictions of the chosen components. An audio file could be played, directly instructing a user on what they should be doing, such as asking them to input data on a scale of how they are feeling, and alerting them when their input has been registered. If using more simplistic measures of differing audio tones, users would require additional training to understand the different alerts prior to studies commencing.

This information, collected via the self-reporting mechanism, would then be processed according to an affective model, and displayed to a user via an interface of dynamic representation. The user would look at the display of their emotional state, making their own interpretations and potentially altering their running behaviour as a result.

'Post-run' a user would also evaluate how they feel and reflect on the run; similar to their actions prior to engaging in the exercise. Users could be presented with the data recorded over a running session upon completion, to reflect on their differing states. A week later, post the study, the user would complete a further questionnaire intending to capture if their opinion may have changed from their instantaneous reflection. As shown in Figure 4.1, the 'one week later' image also highlights feelings of fatigue, not noticed immediately after the completion of a run. Including this later questionnaire is additionally reflective of improvements noted from the analysis of the initial field study, as discussed in section 3.2.1.

This storyboard shows the individual having two separate interfaces; one for user input and one for dynamic representation. It is thought that it would be easier to keep these separate, particularly if a light is used for the interval alerts as a user may get confused between that and the dynamic representation of their emotional state. It is noted however that this is dependent on the constraints of the implementation technology. From this storyboard we can understand that for the self-reporting component a user will need to input data directly into the system. The design of this mechanism is further discussed in subsection 4.3.1.

Having visualised the process and deepened the understanding of what components need to be included in the system, a set of general requirements can now be defined that will outline the overall system design.

4.2 High-Level Requirements

The next task of the design phase is to construct a requirements specification to help guide the implementation of the system. These requirements extend the research questions discussed in the preceding chapter, indicating the system behaviour deemed necessary to answer each of these.

As this project intends to include multiple iterations of implementation, adjusting the system based upon feedback from pilot studies, the requirements are noted at a high-level so that they may be adapted where required. In addition, as the system's main aim is to address the proposed research questions the requirements focus on the core system functionality. If time allows, further consideration may be given to the aesthetics of the system, and at this point additional system requirements will be produced.

In addressing the aims of this research project, the below requirements intend to outline a system that is able of capturing emotional data through self-reporting. Following this the system will make inferences of a user's emotional state on the two dimensions of valence and arousal, prior to communicating these inferences to an end user in a dynamic representation.

The defined requirements are noted below:

1. The system must infer a user's emotional state, mapping this to a value within a two dimensional arousal-valence space.
    1.1 Emotional inferences must be made by the system at regular intervals. These intervals must be appropriately timed to ensure that users are not distracted from their normal running habits.

   1.2 The system must only collect emotional data, for making inferences, from self-reporting mechanisms deemed to be non-obtrusive to a user engaging in exercise.

2. The system's emotional inferences must be communicated to the user through a dynamic representation.

   2.1 The displayed representation must change to reflect the current emotional state inference made by the system. Inferences must be able to represent all possible variations of the available dimensions of valence and arousal.

   2.2 The representation must be easily visible whilst running, without inhibiting a user's normal running posture.

   2.3 Whilst the system is in use, the representation must always be shown to a user.

3. The system must log data for later analysis and reference.

   3.1 The system must collect a user's emotional data at regular intervals, logging this raw input to a file.

   3.2 The system must log the generated inferences made of a user's emotional state to a file.

Requirement one is in reference to the second and third research questions posed, stating the approach of how data must be collected, and the manner in which inferences are to be updated to reflect the current data provided.

The second requirement is a translation of the first research question. To provide an accurate view to end users, the full range of the selected dimensions is required to be used for both the inferences made and the subsequent mapped representation. The necessity for the continuous visibility of the system's inferences is further noted, which will be used in the construction of the main system. However, this will not be applied to one variation of the system which will capture inferences without displaying these to the user. The data collected from this variation will be compared with another variation of the system with an 'emotional' display present. These will seek to address the fourth research question, whether the display of representations 'during-run' impacts a user's behaviour whilst running. Requirement 3 then refers to the system functionality needed for this further analysis. Logged data will help to identify potential improvements to the system and provide the ability to reflect on and understand the gathered data.

The specification as a whole emphasises the importance of using non-obtrusive methods which will not disrupt a user from their given task of running, reflecting research from the literature review and analysis of the initial field study. For this reason, using tools and equipment that are similar to others used by runners will be essential.

Whilst the requirements defined above provide a high-level framework, finer details need to be examined to enable the design of the system to be realised during implementation. The following subsections proceed to comment on this greater level of precision.

4.3 System Design

To enable a clearer conceptualisation of the design, the system will be viewed as consisting of two parts; the logical design, exploring the roles of the system's components and how they collectively interact, and the user interface design, including how users provide direct input to the device. The following logical design section begins by looking at the high-level architecture of the system.

4.3.1 Logical Design

High-Level System Architecture

The specification of the initial requirements allows the components of the system to be defined. Combining these components with their associated relationships will form the basis of the design to be implemented.

The system will consist of the following components:

1. **A self-reporting mechanism –** allowing users to input data regarding their emotions.
2. **A controller** – ensuring data flows between components of the system at set time intervals.
3. **An affective model** – collectively analysing the gathered data from the self-reporting mechanism, making inferences of a user's emotional state.
4. **The dynamic representation** – presenting a user with a timely view of their inferred emotional state, as a result of the system's affective model calculations.

A high-level overview of these components and how they are to interact is displayed in Figure 4.2.

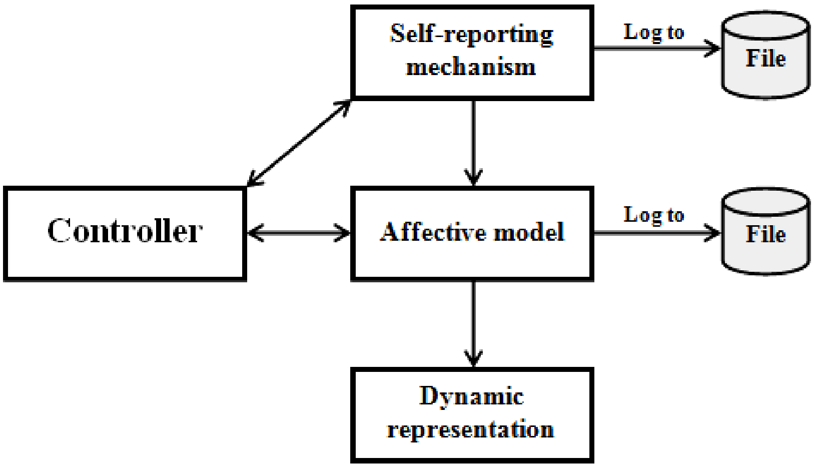

Figure 4.2: High-Level System Architecture Design Diagram

The following subsections of this chapter explore the self-reporting mechanism, controller and affective model presented in this overview in greater depth, making reference to specific techniques and calculations that will aim to be used in the implementation. The dynamic representation of the system will be discussed in section 4.3.2, as part of the user interface.

Components

Self-Reporting Mechanism

Inclusion of a self-reporting tool as part of the proposed system has been echoed throughout this project, with its initial potential highlighted through literature exploration, further consolidated by its illustrated success in the pilot study referenced in Chapter 3. The mechanism is seen as preferable to other detection tools as is deemed less obtrusive, with users also having more control over the data it collects. Whilst the literature survey explored several self-reporting scales and approaches (see section 2.2.3), a decision as to which to implement has yet to be made. The chosen scale and its adaptation to this project are discussed in this subsection.

One method discussed in the literate survey was that of Watson, Clark, and Tellegen's (1988) Positive And Negative Affect Schedule (PANAS). This scale consists of ten positive and ten negative words, with a later expanded version of the scale, called the PANAS-X (Watson and Clark, 1999), including a total of 60 items. The words within this larger set are further grouped into different categories and scales, including basic positive emotion scales of joviality and self-assurance, and basic negative emotion scales of fear and sadness. Although a user would be unable to provide reflection on all items on either scale within the required 40 second intervals of the proposed main study, they would be able to record feelings on a subset of these. To further aid a user in being able to quickly consider and record their feelings within the given interval, it was decided that using word-pairs, such as happy-sad, as a form of scale would be preferable. This was deemed to offer greater clarity of the required input over that of requesting a user to note their level of arousal for a singular emotion, for example excited or timid. Another reason for this decision was that the author felt that by only providing a user with singular positive or negative words it may bias a user's input towards recording at the higher end of the scale for that word.

To decide on the most suitable word-pairs for this project's tool, the most popular words from the initial field study were cross-referenced with those of the various PANAS scales. Table 4.1 highlights the analysis of the chosen word-pairs. The selected positive to negative word-pairs are first presented alongside the words from the user study, presented in Chapter 3, that were deemed most similar. The associated words on the PANAS scales are additionally noted, with the PANAS-X items also highlighting the relevant categories these words are classified within.

Word-Pair		**User Study**		**PANAS Scale**		**PANAS-X Scale**	
Positive word	*Negative* word	*Positive* word	*Negative* word	*Positive* word	*Negative* word	*Positive* word	*Negative* word
Strong	Weak	Strong	Ache Injury	Strong		Strong ~ Basic positive emotion scale ~ Self-assurance	
Happy	Sad	Happy	Sad Bad		Upset	Happy ~ Basic positive emotion scale ~ Joviality	Sadness ~ Basic negative emotion scale ~ Sadness
Energetic	Tired	Energised Buzzing Bouncy	Tired			Energetic ~ Basic positive emotion scale ~ Joviality	Tired ~ Other affective states ~ Fatigue
Enthusiastic	Disinterested	Motivated		Enthusiastic		Enthusiastic ~ Basic positive emotion scale ~ Joviality	
Relaxed	Nervous	Relaxed	Nervous Stressed		Nervous	Relaxed ~ Other affective states ~ Serenity	Nervous ~ Basic negative emotion scale ~ Fear

Table 4.1: Self-Reporting Tool – Word-Pair Analysis with PANAS Scales

As seen above, the majority of the selected positive words come from the PANAS-X basic positive emotion scale of joviality. Watson and Clark's (1999) commentary on the construction of these scales provides some insight for this; noting that positive descriptors are more interrelated, thus there is difficulty in partitioning these words into more distinct categories. However as joviality is deemed to be "the most reliable of the lower order scales" the decision to use more words from this group seems appropriate.

By conducting this cross-referencing with the PANAS scales, that are proclaimed to be "strongly correlated with other existing measures of shorter term affect" and have been previously reported in literature (Watson, Clark, and Tellegen, 1988; Watson and Clark, 1999), we have provided validation for the use of these words within a future study. Whilst the selected negative words of weak and disinterested have not been correlated to the PANAS scales, nor are a direct translation of items recorded in the initial field study, the author perceived them to be the antonym of their validated positive word-pair. These words will seek to be further validated in a pilot of the main study, with an understanding of their use amongst participants agreed.

As part of the main study of this project, it is envisaged that for each interval in the running session a user will input data in reference to each word-pair. This raw input will be logged to a file for a user to view and reflect on 'post-run', and also used as part of the affective model discussed next.

Affective Model

The aim of the model component of the system is to make 'during-run' inferences of a user's emotional state at multiple intervals, using data collected via the self-reporting mechanism. As discussed in the subsection above, the self-reporting mechanism will make use of word-pairs, thus it is now necessary to decide upon the type of data that will be recorded against each of these. The system requirements specify that inferences are to be made within a two-dimensional space of valence and arousal. With the selection of the word-pairs denoting the valence dimension, the data captured will therefore need to indicate the arousal a user feels towards either part of the word-pair. For this reason a 5-point scale from 1 to 5 will be used. A recorded value of 5 will represent greater current identification with the positive side of the word-pair, whilst a recording of 1 inclining towards the negative. Although this scale is not continuous it should provide enough input variations to allow for valid inferences to be made, that present insight into the emotional state of an individual, whilst not resulting in additional complication for implementation. It is however noted that even the selection of only 5 scale points may need to be revised during the implementation phase, dependent on the constraints of the chosen physical components. Another contributing factor in this decision was the necessity for users to be able to quickly specify their level of arousal; selecting from a greater range of values was thought to cause delay.

With the knowledge of the form of the data to be collected, we next discuss how the model will make inferences from this. Due to a greater research focus being placed on the evaluation of the impact the system might have on a user, and the resolution of the challenges of implementing a system suitable for a physical setting, only a simple affective model will be used. This model will collect the values recorded for each word-pair for each interval and sum these to enable an average of the values to be calculated. The range of possible averages in relation to the scale may then be mapped to differing dynamic representations, for instance a high average could result in more lights on a display being lit up. If a user is unable or does not record data for each of the word-pairs in an interval the system will make an average of those word-pairs that have recorded input. Although this will not provide a full representation of a user's emotional state it is seen as a valid alternative for the incomplete input. The likelihood of this occurring should be minimal as users will be provided with training prior to system usage, highlighting the process of data input expected during running study sessions. Pilot studies, undertaken prior to the main study, will also aim to further test that the training is suitable, the intervals are of an appropriate length and that the model generates the expected average output. At each interval the current emotional state will be captured independently, thus no relationships will exist with previous emotional states. This decision was made as allows a user to see more distinctly any changes in their state.

A further point of consideration is that individuals may place different values on certain emotions or word-pairs, particularly dependent on the type of run they are undertaking. For example, on a training run an individual may pay less attention to how energetic or tired they feel as they will be running at a potentially more reserved pace. This theory is supported in literature, whereby an emotion is seen to be a “judgement of value” with individuals appraising emotions according to their own interests (Oatley and Johnson-Laird, 2014). For this reason, to enable the affective model to be better adapted to individuals and their goals, the system should allow users to specify the weighting they place on each word-pair. The detail of how this is accounted for is discussed in Chapter 5.

Controller

Highlighted in the high-level architecture in section 4.3.1, the system will include a controller component that synchronises the data flow between the self-reporting mechanism and the affective model, ensuring emotional state inferences are generated at set intervals. The controller will also manage the initiation and closure of the program running on top of the system, alert the user to when they need to provide data input, provide confirmation that input has been recorded and alert users that the dynamic representation has changed to reflect their current emotional state. The data recorded for each word-pair will be collated by this component before being passed to the affective model. When all inputs for the interval are sent to the affective model and the representation has changed, the controller will ensure that no further inputs are recorded until the next interval begins. If data is not entered for all word-pairs at the end of each interval those that have been recorded will flow through to the model. A further feature of the controller will ensure that the raw input of users, the generated inferences and their representation mappings are logged to a file in a clear format; these can then be easily viewed and interpreted upon completion of a run session.

From the initial user study it was concluded that a 40 second interval between data entries could be suitable for future studies. However, this interval has not been tested with the selected word-pairs and the physical components of the self-reporting mechanism. Testing in a pilot user study, prior to full system usage, will be conducted to confirm the interval spacing, allowing enough time for data input and a few seconds of rest in each interval. The length of the run may also impact the decided interval length, ensuring enough recordings are collected for analysis.

With an understanding of the components that make up the logical design of the system we can now focus on the user interface, including the dynamic representation component; discussing the challenges and potential solutions for a system design capable of being used and interpreted in a physical setting.

4.3.2 User Interface Design

A critical part of Affective Computing is centred on how users interact with a system. In a physical setting this is particularly important due to constraints imposed by the environment. Therefore affordances should be incorporated into the user interface design to ease system use. An initial examination of how a user may interact with the proposed system of this project was conducted through the storyboard in section 4.1. This subsection explores in more detail designs and layouts that could support the logical design. A number of these proposed ideas may need to be further adapted dependent on decisions made within the implementation phase, and will be improved upon with each iteration of the user studies. The two main factors that need to be considered throughout this discussion are the creation of a design that can be easily adapted to runners of different sizes, and one that is considered to be non-obtrusive for the given task of running.

The first part of the design that needs to be explored is how the device could be held by the user. As noted in the initial field study, runners are familiar with using sports watches and fitness trackers, thus creating some form of holder that could be attached to this area would be beneficial. This would also provide advantages for self-reporting as minimal movement would be required from the user to register input. The most suitable and practical design would therefore be for the system to be attached to either a running top's or individual sleeves, as depicted in Figure 4.3. A preference is given for detachable slip-on sleeves as these could easily stretch to adapt to the size of a participant's arm. Alike to many of the decisions made within this chapter, the final design will only be evident once the system is built and the size of the device is known.

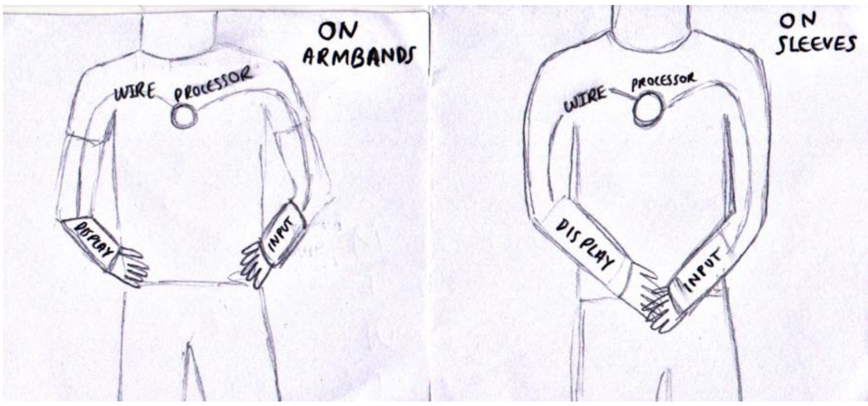

Figure 4.3: System Holder Designs

Reflecting the storyboard presented in section 4.1, a different sleeve would be used for the self-reporting mechanism and dynamic representation. The more detailed designs of these two differing user interfaces are explored next.

User Input

The main interaction a user will have with the system will be via a self-reporting tool, whereby a user will provide direct input regarding the emotions they perceive they are experiencing. A number of differing low fidelity prototypes have been created to begin to visualise potential designs that could be placed on a sleeve:

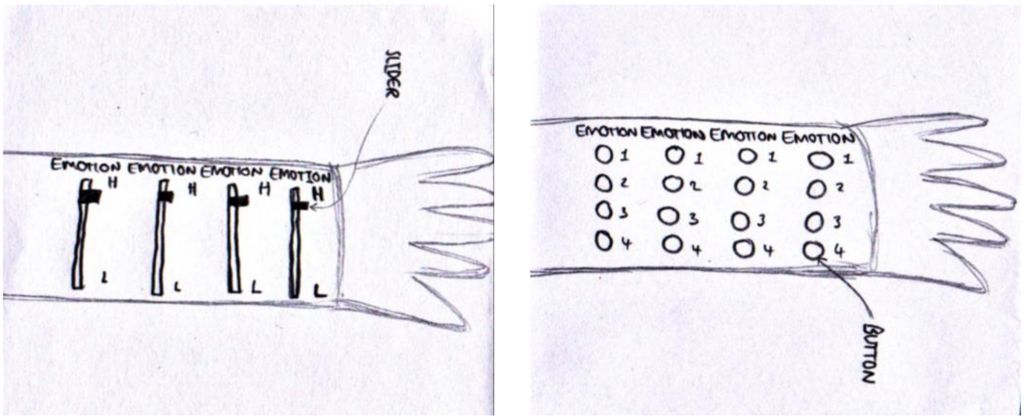

Figure 4.4: System Garment Designs – Buttons and Sliders

It is thought that the arousal scale, required for the affective model, as discussed in section 4.3.1, could be indicated by using either a sliding component or individual buttons for the different scale ranks (see Figure 4.4). Whilst the slider would allow for a more continuous scale to be used, it may be difficult for a user to operate whilst running. A user might also avoid pushing the slider to the end of each side of the scale, thus only a restricted range would be used. The use of buttons denoting integer values is therefore seen as preferable. The size of the buttons will however need consideration during implementation, to ensure that they are large enough for users to push easily in an active environment. Appropriate labelling will also need to be provided for each button so users are aware of the input they are recording.

In Figure 4.4 designs are shown where emotions are seen to be ranked individually in terms of arousal, high to low. It was however decided in section 4.3.1 that word-pairs would be used, thus an updated design to reflect this can be seen in Figure 4.5 below.

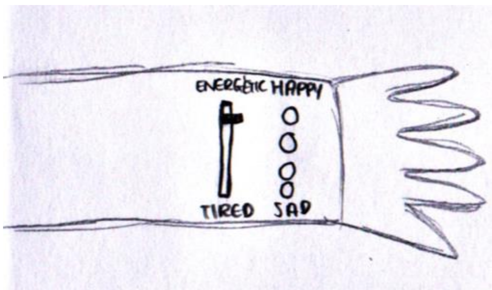

Figure 4.5: System Garment Designs – Word-Pairs

As part of the initial user interface design the orientation of components was also considered, to determine whether arrangements along the arm or down the arm would be easier to operate. A drawing of an along the arm set-up is shown in Figure 4.6, with the previous figures presented in this subsection highlighting a potential vertical placing of components.

To test the suitability of both approaches the author undertook a run, with an arm compression bandage on their arm, mimicking the actions required for interacting with these proposed designs as they ran along. The conclusion was that a vertical layout felt more natural; similar in placing to a sports watch the author usually wears. Further pilot studies will be conducted with a larger group of users to test the orientation of the built system, so adaptations can be made before the main study commences.

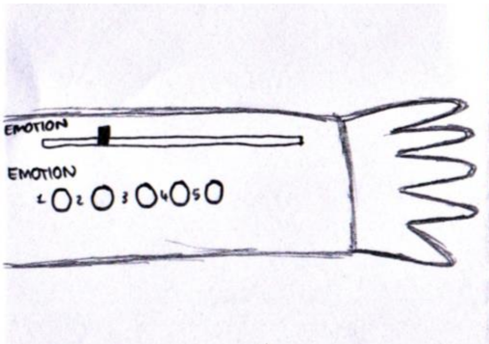

Figure 4.6: System Garment Designs – Horizontal Layout

Another idea that was originally contemplated was that ‘word buttons’ could be grouped together in a grid layout, as shown in Figure 4.7. It was thought that a user could press the buttons corresponding to the emotions that they felt during each interval. Whilst this would provide flexibility for a user, able to select different words in different intervals, the format does not record data that would indicate the arousal that a user felt towards each of these emotions. This would result in requirement one being unable to be fulfilled. The grid concept would also be difficult for a user to quickly use, as they would need to find and locate emotions at each interval. The way in which the words are presented may also provide bias. The design with two different grids, one of positive and one of negative words, could better assist the user in being able to identify where the button for the emotion they which to record is located, but this would still present delay. For these reasons, this idea will not be taken forward.

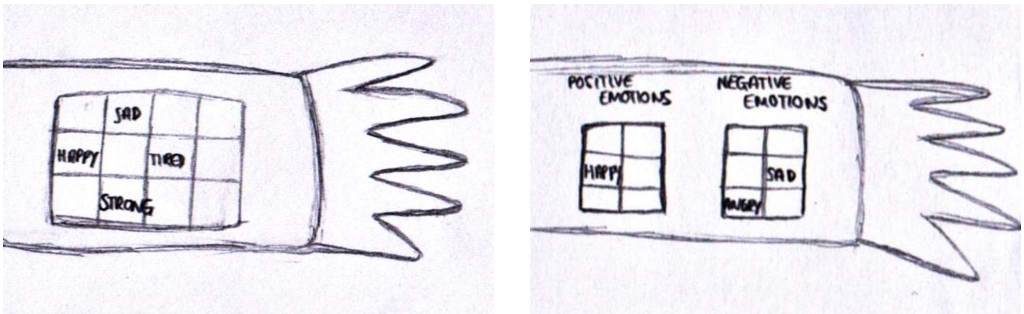

Figure 4.7: System Garment Designs – Grid Layout

In conclusion, the use of buttons in a vertical alignment is the design intended to guide the implementation. However as noted throughout, the number of buttons may need to be minimised dependent on component restrictions. A suitable alternative could be to have one set of scale buttons, with a user recording data on the same scale for each word-pair sequentially. This is discussed in further detail in Chapter 5.

Dynamic Representation

The other key interactive element of the system will be the dynamic representation of a user's emotional state, in relation to the first research question of this project. The representation needs to reflect the inferences generated from the affective model, with a pre-defined mapping from possible inferences to the dynamic output to be displayed to a user. As specified in section 4.3.1, the output of the affective model of the system for each interval will be the average of the recorded values for each word-pair. As these word-pairs may have different weightings, selected by a user, the average could be a floating point number. For this reason, a range of possible averages should be a mapped to each chosen representation. The author, upon consideration of expected system constraints, has decided that five differing states will be used, with the higher averages displayed as a more positive state.

With the granularity of the representations decided upon, this discussion now focuses on the form these states may take. The first idea considered was the use of audio output, with different tones or spoken words denoting the different representative states. This approach could be beneficial as a user would not be required to actively seek the representation, instead able to continue focusing on their given task of running. On the other hand, it was felt that the audio may not be able to be easily distinguished by a user, particularly if audio is also used to alert a user to time intervals and their need to self-report.

Another more preferable idea was that of using light, as inspired by the work of Snyder et al. (2015), discussed in the literature survey in Chapter 2. Using multiple small lights the full range of emotional state inferences could be mapped and displayed. However, a challenge presented by using lights in an outdoor setting is that the colour presented may be viewed differently, thus interpreted incorrectly by a user. To minimise the impact of this users should be introduced to the system and shown potential representation light combinations outdoors before they engage in a full user study. With larger lights the chances of misinterpretation are also minimised. In addition, due to the active and outdoor setting, the intensity of displayed lights should not be used to indicate differing emotional states as a user may not be able to depict brightness changes, particularly if these are minimal between the interval representations.

As a starting design the author has decided that three lights of different colours will be used, and placed vertically on the opposite wrist to the self-reporting interface. This decision will be used in the initial physical prototype of the system, with further testing confirming the practicality of the design, particularly with regards to the visibility of the representation in outside lighting. The size of the lights and the fixed brightness will also be tested during implementation to ensure that these are suitable.

The range of averages that the affective model could generate will be divided into five sub-ranges, as noted earlier. Each of these ranges will be mapped to a specific light combination, indicative of a user's emotional state. It is proposed that a green, orange and red light are used for the system, and as such the suggested light combinations and mappings for these colours are noted in Table 4.2. The colour of these lights may have to change however, dependent on physical components available, and whether users feel that they can clearly identify each distinctly; this will be investigated further through a pilot study.

Light combination	**Affective model range to map**
Green	> 4 and < = 5
Green and Orange	> 3 and < = 4
Orange	> 2 and < = 3
Orange and Red	> 1 and < = 2
Red	> 0 and < = 1

Table 4.2: Dynamic Representation – Light Combinations

Conclusion

With the decisions made for the dynamic representation, an overall design for the system was presented. The design framework created in this chapter will now be taken forward for use in the implementation phase; adapted as required, whilst still ensuring that the developed system is capable of providing insights for the posed research questions in section 3.3. The framework is intentionally open for several possible implementation routes to accommodate iterations over the physical form and operation required by runners in-situ.

Chapter 5

Implementation

In Chapter 4 the initial design of a system that could support the exploration of the posed research questions was presented. This work consolidated key design decisions, defining the necessary requirements for creating a system capable of inferring a user's emotional state within the arousal-valence space at regular intervals, displaying inferences in a form that can be easily interpreted by a user whilst they are running. This chapter makes use of these ideas, extending and adapting where necessary, in the implementation of two alternative systems that are capable of addressing the objectives of this project.

The chapter begins by providing an overview of exploratory work undertaken in the creation of an initial prototype system. This Arduino-based implementation was used to capture concepts for physical interaction and minimal display. The main prototype implementation, a mobile application named EmotiRun, is then discussed alongside a high-level presentation of the workflow between the different screens displayed to users. Detailed discussions on the individual components will then follow, with attention being drawn to the core functionality.

Extracts of EmotiRun code is used throughout the chapter to support the narrative, with the full code library available in Appendix D.2 and within the uploaded project directory.

5.1 Initial Prototype

With a consolidated design, potential technologies and tools that could be used to implement the system began to be explored. One technology that appeared to be of use was an Arduino Uno. This microcontroller is capable of collating inputs from interfacing components, and generating calculations from these, a key feature required of the system. The vast range of Arduino components available was also seen to be of benefit, allowing flexibility in exploring how to implement the necessary functionality whilst considering the usability of the interactive features. Furthermore, the selection was preferable due to the author's prior experience with the technology, having previously implemented a core part of the design, a form of light display, in a previous project. For these reasons an initial prototype was created using the Arduino Uno, with wires, buttons, LED lights and a buzzer component. The code and a demonstration video for this prototype are available within the uploaded project directory, and a picture of the system is shown in Figure 5.1 below.

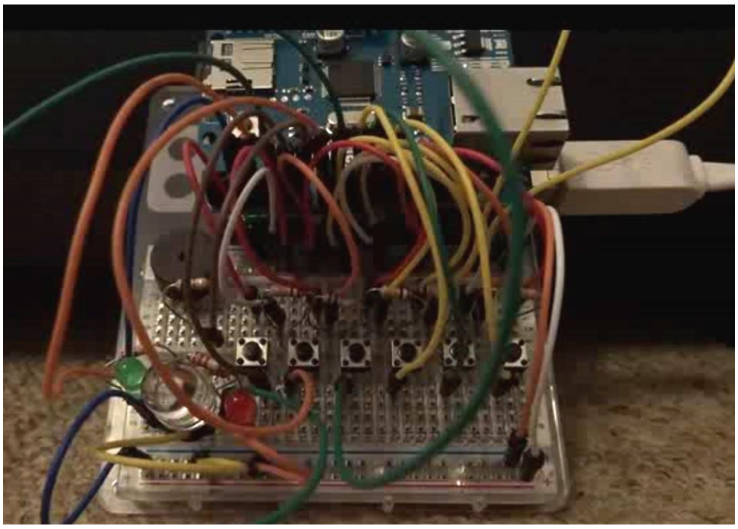

Figure 5.10Arduino Uno – Initial Prototype

This prototype made use of five buttons to represent a 5-point scale. With an additional button used to start and end the program. Reflective of the work in section 4.3.2, due to the space restrictions of the device it was decided that only one set of scale buttons would be used to record data in relation to all of the word-pairs. Three LED lights were also added, for the dynamic display of a user's emotional state; with colours of green, blue and red selected due to component availability.

Interacting with the prototype, each interval, implemented within the program using a timer variable, a user was required to provide input for the five word-pairs. A user was alerted to the start of an interval by a buzzer tone, also indicating that input should then be given in reference to the first word-pair. The user would select the scale button they felt reflective of their current feelings in relation to the word-pair, with the corresponding value recorded. This input was acknowledged by the system by a differing tone, and was also used to signal that input for the next word-pair should then be entered. When input was provided for all word-pairs the collected values were summed and an average was calculated. Following design decisions in section 4.3.2, the range of possible averages that could be generated were split into five sub-ranges, with each of these ranges relating to a distinct combination of lights. The light combination associated with the calculated average, the inference of the user's emotional state for a single interval, was subsequently displayed to the user. No further data was then able to be recorded until the next interval begun.

Despite the initial success of this prototype a number of implementation challenges started to arise. The first of these challenges was in implementing voice recordings to instruct users on the input they should be providing, a feature highlighted in the storyboard in section 4.1. Whilst the buzzer element allowed the use of differing tones, upon listening to the possible variations it was felt that they were not distinct enough for a user to be able to clearly distinguish between them, particularly when a user's primary focus would be on the given task of running. Although specialised media player Arduino components exist, integrating them with the main microcontroller was deemed beyond the scope of the time and financial constraints of this project. The storage of the collected data for later analysis presented additional difficulty. Due to the limited memory space on the Arduino itself, it was discovered that an external storage solution would be required. Despite exploring a number of potential solutions, including the use of an SD card, these attempts were unsuccessful and the issue remained unresolved.

The main challenge however, was how the design could be translated into a wearable format, suitable for use whilst running. As shown in Figure 5.1, the Arduino system has numerous wires and components that could easily fall out in the given context. The design was also difficult to use due to the closeness of the components, as a result of the space constraints of the device. Whilst the wires could have been extended and potentially soldered to the central board it was felt that the system may still not have been robust enough to enable reliable data collection.

As a result of these problems it was decided that the system should take a different and more suitable form, and thus a new technology was explored.

5.2 Main Prototype

As discussed in the previous section, the key concern of the Arduino prototype was how a user would be able to hold it and provide input whilst active. Reflecting on the initial field study, where it was highlighted that a number of users carry mobile phones whilst running, it was decided that a suitable alternative implementation could be a mobile phone application. This section will discuss the technology of the developed application, EmotiRun, as well as provide an overview of the screens presented to the end user and the key functions that support these.

Of note, whilst no further progression was made on the Arduino prototype, the main features implemented, including the calculation of averages and the interval timer, were similar to those required of EmotiRun. As a result, much of the code was simply translated into the new program, which will become evident in the subsections to follow.

5.2.1 Technology Used

With a mobile application decided upon, the platform on which to implement had to be chosen. Due to the availability of a suitable phone on which an application could run, the Android platform was selected, with the EmotiRun directly uploaded to a Samsung Galaxy Nexus. This decision was also influenced by the author's prior experience with the Java programming language used in the development of Android applications. The event-driven nature of Java was additionally seen to be of benefit as the required system needs to collect data from users at set intervals, capturing the values of the buttons that they press.

5.2.2 Displayed Screens

EmotiRun consisted of two screens shown to users; the landing screen and the input screen (see Figure 5.2).

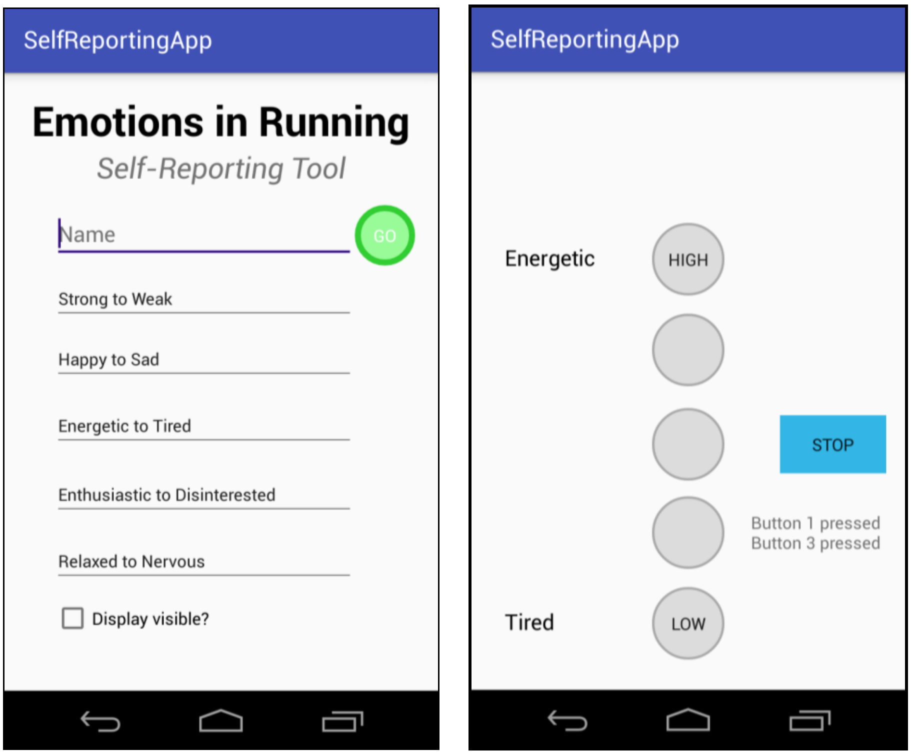

Figure 5.2: EmotiRun – Landing Screen and Input Screen

When the application is first started the user is presented with the landing screen, the left-hand image above. When all details have been completed on this screen the GO button may be pressed and the input screen will then be displayed. Pressing this button also starts a timer, used to calculate the intervals in which the user is required to provide input. As a participant completes their run they press the stop button which stops the timer and allows no further input. An email button will then appear which should be pressed to send data captured for the current use of the application. To complete the current session the end button, which appears after an email has been sent, may be pressed which brings the user back to the landing screen.

Having briefly highlighted how users can navigate between these screens, they will now be discussed individually in more detail, with reference made to the critical functions that enable the self-reporting feature and the 'emotional' display, the inference of the user's emotional state.

Landing Screen

The landing screen has a minimalist design, with its primary purpose being to capture the configuration information for the run being undertaken.

As discussed in section 3.2.3, the significance of particular runs changes for each runner, depending on their personal goals and expectations. Thus a ‘weightings’ function was implemented to allow any given runner to vary the emphasis they wish to place on each of the five word-pairs. The values of these weightings are captured in the five labelled input fields.

To enable the evaluation of the fourth and fifth research questions, regarding whether users are affected by a dynamic representation ‘during-run’ and potentially view a run more positively ‘post-run’ as a result, the main user study will require participants to undertake two runs. On one of these runs data will be recorded but no display will be present, and on the other inferences of a user’s emotional state will be shown in a dynamic representation. It is the comparison of these two instances that should give rise to addressing the posed questions. The checkbox at the bottom of this screen allows the necessary configuration to be captured.

All of the data provided on this screen is required to be used within the set-up of the following input screen, thus it needs to be stored for future recall. The code for this is implemented within the goToInputScreen function as follows:

```
public void goToInputScreen(){
    Intent intent = new Intent(this, InputScreen.class);

    intervalBeginPlayer.start();

    intent.putExtra("Username",userName);

    intent.putExtra("StrongToWeak",weightingValue1);
    intent.putExtra("HappyToSad",weightingValue2);
    intent.putExtra("EnergeticToTired",weightingValue3);
    intent.putExtra("EnthusiasticToDisinterested",weightingValue4);
    intent.putExtra("RelaxedToNervous",weightingValue5);

    intent.putExtra("DisplayStatus", displayVisibility);

    startActivity(intent);
}
```

Input Screen

The input screen implements the core functionality of EmotiRun, namely the self-reporting tool and the ‘emotional’ display. The main components of this screen are discussed in the next subsections, in relation to the high-level architecture diagram presented earlier in Figure 4.2.

Self-Reporting Mechanism

Every interval, for each word-pair a user is required to press one of five displayed buttons, indicating how they are currently feeling. To detect these button-presses a listener function is implemented on each button. The associated value of the button pressed, multiplied by the weighting given to the current word-pair, is subsequently stored.

```
buttonScale5.setOnClickListener(new View.OnClickListener(){
    @Override
    public void onClick(View v){
        inputArray[wordPairCount] = 5 * weightingArray[wordPairCount];

        // If input is not collected for all word pairs for an interval the
        // average is calculated for the word pairs recorded, and their
        // associated weightings. A totalWeighting array is needed for this
        // purpose
        totalWeighting += weightingArray[wordPairCount];

        // Checks if it is the start of an interval to add appropriate
        // heading text to the data string
        newIntervalCheck();

        // Adds input value to the data string
        intervalDataText.add(inputArray[wordPairCount] + ", ");

        wordPairCount++;

        // Checks what step is next and starts the appropriate audio or
        // executes the appropriate calculation
        checkNextStep();

        // Updates a text label so the user is aware that their button press
        // has been logged
        buttonPressLog.append("Button 1 pressed \n");
    }
});
```

A key design principle, as described in work by Don Norman (2013), is providing feedback of a system's status to allow a user to continue with their given task. When users press the buttons on this screen it is therefore important to make them aware that their input has been logged. A label stating the buttons that have been pressed for the interval, located at the bottom right of the screen, provides this as shown in Figure 5.2.

Affective Model

The role of the affective model component is to collect the input provided for the word-pairs each interval, to make an inference of the user's emotional state. The calculation is to be made immediately after input has been received for all five word-pairs in a given interval, or at the end of the interval, if data has not been captured for every pair. This second instance affords a slight limitation as the inference would not be representative of all word-pairs. Users will however be trained in application usage so it is unlikely that this will occur. The model, implemented within the representationFunction, sums the given inputs with their respective weightings, and calculates an average as shown on the following page.

```
// Adds the values recorded for the current interval
for (int i = 0; i < 5; ++i){
    inputTotal += inputArray[i];
}
```

```
// Calculates an average of the inputted data for the interval,
// dependent on the number of values captured
inputTotal = inputTotal / totalWeighting;
```

Dynamic Representation

The dynamic representation was implemented using three round inactive buttons as icons. This design is reflective of the work in section 4.3.2, and the Arduino prototype discussed earlier in this chapter. These buttons are representative of a traffic light rating system, and thus the colours of green, amber and red were used. Also discussed in section 4.3.2; the combination of 'lights' displayed to a user is dependent on the average generated from the affective model. Two combinations are displayed in Figure 5.3.

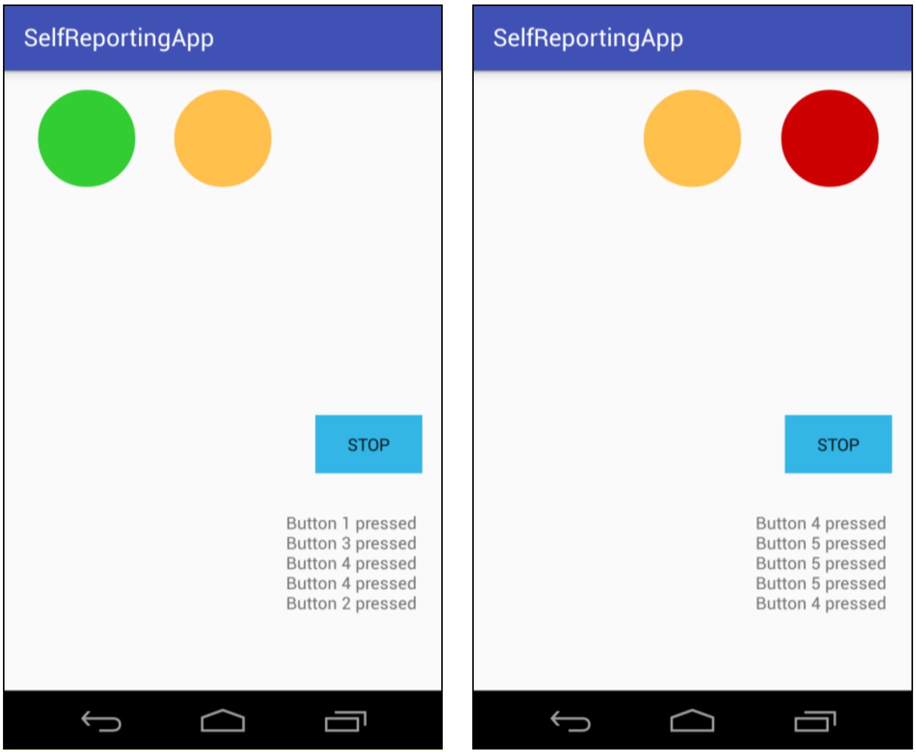

Figure 5.3: EmotiRun – Light Combinations

Controller

A key element of the high-level architecture, presented in Figure 4.2, is that of the controller component. The primary role of this component was to ensure the implementation of regular intervals in which inferences are to be made, synchronising the flow of data from user entry, through the affective model to the dynamic representation. This feature was implemented using a handler:

```
handler.postDelayed(new Runnable(){
    @Override
    public void run(){
```

```
        // Executes operations every 40 seconds
        handler.postDelayed(this, 40000);

        runOnUiThread(new Runnable(){
            public void run(){
                intervalBeginPlayer.start();

                wordPairPart1.setText("Strong");
                wordPairPart2.setText("Weak");

                // If no input has been entered for the interval
                if (wordPairCount==0){
                    // Adds the interval heading text and notes that no data
                    // was captured
                    newIntervalCheck();
                    intervalDataText.add("None, ");
                }

                /*
                 * If input has not been gathered for all word pairs for an
                 * interval then no 'emotional display' will have been shown
                 * Therefore, at the end of the interval the representation
                 * calculation is made with the input recorded
                 */
                if (!repCalcCheck.equals("calculation done")){
                    repCalcCheck = "calculation to be made without all
                                                                inputs";
                    representationFunction();
                }

                // Resets the variables and the display
                wordPairCount = 0;
                inputTotal = 0;
                totalWeighting = 0;
                repCalcCheck = "not calculated";
                buttonPressLog.setText("");

                buttonScale5.setVisibility(View.VISIBLE);
                buttonScale4.setVisibility(View.VISIBLE);
                buttonScale3.setVisibility(View.VISIBLE);
                buttonScale2.setVisibility(View.VISIBLE);
                buttonScale1.setVisibility(View.VISIBLE);

                wordPairPart1.setVisibility(View.VISIBLE);
                wordPairPart2.setVisibility(View.VISIBLE);
            }
        });
    }
```

Whilst the interval length is currently implemented as 40 seconds, reflecting discussions in section 4.3.1, this may change upon the evaluation of a pilot study. At the end of the interval this function also resets the graphical display, ready to allow input for the next interval to be captured.

The controller also acts to alert the user as to when to provide input, through the use of audio recordings; overcoming the challenge presented by the earlier Arduino prototype. When a user clicks the GO button on the previous landing screen this audio begins. The first audio track played is: “interval begin, strong to weak”. When a user presses one of the buttons another audio recording is played announcing the next word-pair for which to provide data. When data has been captured for all word-pairs “interval complete” is sounded, and if the ‘emotional’ display has been configured for this run, it alerts the user that the inference of their emotional state is about to be displayed.

A minor limitation of the audio function is that if users press one of the buttons before the whole of an audio track has played, the next audio track starts to play over it. Whilst users will be briefed on this as part of the training, prior to the main study, labels for which word-pair data is currently being recorded for are also displayed to provide more clarity.

As specified earlier, the intervals are only ended when the user presses the end button on the screen, signifying the completion of the running session.

Data Logging

As part of the requirements in section 4.2 it was noted that the system must keep a record of provided user input and emotional inferences made. Thus, upon the completion of an interval EmotiRun logs the input values, calculated average and displayed combination of ‘lights’ (noted in letter abbreviation form) to an array string, with logs for each subsequent interval amended to the end. When the program is stopped and the email button is pressed this data is added to the main body of an email sent to the author, including additional configuration details captured in the input screen. This data can also be emailed to study participants if requested.

```
emailButton.setOnClickListener(new View.OnClickListener(){
    @Override
    public void onClick(View v){
        // Gets data input from previous screen
        String userName = getIntent().getExtras().getString("Username");
        String displayOption =
                         getIntent().getExtras().getString("DisplayStatus");

        String intervalDataSet = TextUtils.join("; ", intervalDataString);

        Intent emailIntent = new Intent(Intent.ACTION_SEND);

        // Destination email address
        emailIntent.putExtra(Intent.EXTRA_EMAIL, new
                                        String[]{"username@gmail.com"});
        // Participant name
        emailIntent.putExtra(Intent.EXTRA_SUBJECT, userName);

        // Interval data, weightings and display option
        emailIntent.putExtra(Intent.EXTRA_TEXT, intervalDataSet + ",
            WEIGHTINGS: " + wordPair1 + ", " + wordPair2 + ", " + wordPair3
            + ", " + wordPair4 + ", " + wordPair5 + ", DISPLAY SETTING: " +
            displayOption + ".");

        emailIntent.setType("message/rfc822");
        startActivity(Intent.createChooser(emailIntent, "Choose email
            client..."));
```

```
        endButton.setVisibility(View.VISIBLE);
    }
});
```

This chapter has presented two implementations of the design concept described in Chapter 4. With the completion of the implementation of the application, the next chapter explains how the main user study for the project was designed and carried out. EmotiRun was designed and constructed specifically for this study, collecting user data and logging generated inferences which have the potential to address the research questions posed in section 3.3.

Chapter 6

Main User Study

To address the research questions specified in section 3.3, a user study was undertaken in a naturalistic setting that made use of the EmotiRun application presented in Chapter 5. This study involved participants undertaking two 1 mile runs, one with an ‘emotional’ display visible, and the other without. The ‘emotional’ display, as discussed in Chapter 4 and Chapter 5, is a dynamic representation of a user’s emotional state inferred from self-report input.

This chapter starts by introducing the study questions to be explored, highlighting the data that is required to be captured to enable possible insights for these. The set-up and procedure of the study is then discussed, before the results are presented and analysed, drawing upon gathered quantitative and qualitative data. The analysis of this study will be further reflected upon from a broader perspective in Chapter 7.

6.1 Study Questions

The focus of this project is on the investigation of the research questions raised in section 3.3. The first three questions, restated below, have been explored in previous chapters, resulting in the implementation of EmotiRun, the application to be used in this study.

Research Question 1: How could a user’s emotional state be dynamically represented, for user interpretation, in an active setting?

Research Question 2: How could we collect data input from users in a non-obtrusive and non-invasive way, in an active setting?

Research Question 3: How might we use collected data to make inferences of a user’s emotional state within a two-dimensional space of valence and arousal?

Thus, this study will look to address the fourth and fifth research questions. These are redefined, specific to two variations of EmotiRun, as follows:

Study Question 1: Are users' self-report ratings of the five presented word-pair dimensions influenced by the dynamic traffic light 'emotional' display of EmotiRun during a run?

Study Question 2: Do users view a run more positively 'post-run' as a result of being exposed to the dynamic representation of EmotiRun?

The first study question makes use of EmotiRun self-report inputs for the five word-pairs, recorded at intervals on each run. To address the question, the values of these five dimensions were used to compare runs with and without the 'emotional' display.

The second study question makes use of the pre- and post-run states of the users to contrast each run. Comparisons of these states for individual runs and across each study session (pre-run one state vs. post-run two state) are expected to provide insights in which to address the posed question.

6.2 Study Design

The primary aim of this study was to address the study questions discussed above, using EmotiRun as a supportive tool. Two groups of participants were therefore recruited, who used variants of the application in a different order. One group of participants were able to view the 'emotional' display on their first run, and the other group were able to view it on their second, to control for order effects.

The following subsections will discuss the constructs of the study and the selection of participants in more detail. This study complied with the ethics checklist provided by the Computer Science department. The completed form may be found in Appendix A.2.2.

6.2.1 Participant Selection

In total nine participants were recruited; one for the pilot study, and eight for the main study. These participants were an opportunity sample, consisting of runners known to the author. All but one of the participants were aged between 19 and 23; with one male for the pilot and an equal split of males and females for the main study. The participants were allocated to the groups described in section 6.2, with four participants in group one (viewing the 'emotional' display first) and four in group two.

Participants were selected with an average running pace that matched that of the author. This was a necessary requirement so the author could run alongside a participant during the study sessions to capture incidents that could potentially be used as additional data. For instance, what users were saying whilst interacting with the application, and conditions that may have affected the inputs provided. All the participants had previous running experience, with 50% having trained for and completed a half marathon (13.1 miles) a week prior to the study.

6.2.2 Study Setting

The study involved participants undertaking runs along the same route around the university campus (for six participants) or around the author's home location (for two participants).

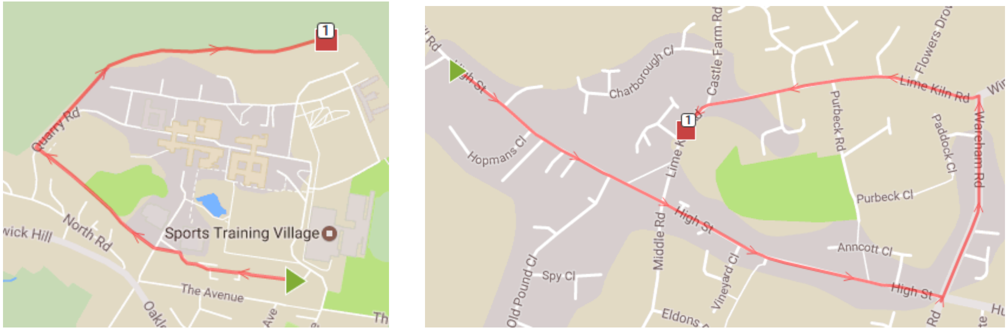

Figure 6.13Main User Study – Running Routes

This outside setting was selected as a primary aim of this project was to explore the posed research questions in a natural context. On the first session participants ran one mile out to a specific point, with the second one mile run returning along the same route. The first run was designed to be more strenuous, involving a segment of moderate incline, allowing the terrain of the second run to be easier.

All participants provided input on the same device; a Samsung Galaxy Nexus phone with the EmotiRun application installed. This device was carried by a participant whilst they ran, as shown in the pictures below. Participants were also invited to bring their own running headphones to listen to the audio cues, or otherwise provided with a pair by the author.

Figure 6.2: Participants Using EmotiRun During the Main User Study
(Images included by permission)

On the run in which EmotiRun was configured to show the 'emotional' display, the dynamic representation was visible to a user at the top of the screen, seen previously in Figure 5.3. At the beginning of this run participants were informed that they could look at this display throughout the run, as they deemed necessary.

6.2.3 System Configuration

Three aspects of EmotiRun could be configured prior to the overall study commencing and immediately prior to individual running sessions. These configurations were designed to enable different variations of the application to be presented to a user, with the dynamic representation of their emotional state also able to be tailored to their personal expectations.

The first of these features was the length of the intervals. This variable was set at 40 seconds within the handler function of the code, discussed in section 5.2.2. Whilst this length was previously used and tested within the initial field study (see Chapter 3), it has not been tested for suitability in the current implementation where five sets of input, in relation to the word-pairs, are required from a user each interval. As a result, the system was designed to be reconfigured with a different interval length upon the outcome of a pilot study.

Secondly, the ‘emotional’ display can be set to be shown or hidden for a given run on the landing screen of the application. As noted in section 5.2.2, evaluating runs a participant undertakes with these two different variations of the system is expected to provide insights with which to address the second study question raised in section 6.1.

Finally, the ‘weightings’ function, also implemented on the landing screen, allows each runner to choose which word-pairs they feel are of more importance to their own running goals. These weightings are to sum to a total of 10, and to remain the same for both runs undertaken as part of the study.

6.2.4 Procedure

Prior to the commencement of study sessions participants were requested to complete two online forms, the questions of which may be found in Appendix B.1. The first form was to provide an overview of the study and obtain consent for study participation, ensuring that the required two mile distance of the sessions had been recently covered. Upon completion of this form participants were randomly allocated to a specific group, dependent on which variation of EmotiRun they would be presented with first, as discussed earlier in section 6.2. Participants were also asked to complete a running habits questionnaire, a subset of the questions presented in the ‘pre-run’ questionnaire of the initial user study (see section 3.1). These responses will be reflected on in relation to the collected data in the analysis of the study, presented in section 6.4.

At the start of each study session, participants were again invited to review the study brief (originally presented in the first online form and available in Appendix A.2.1). Basic verbal training in application usage was also provided at this point. This included an introduction to the word-pairs of which they would be expected to give input for. The desired weightings for each word-pair were then discussed and set with each participant, with the same values used for both runs of the study session.

Immediately prior to the first run participants were asked a few short questions (see Appendix B.1.3) to record their current emotional state and feelings towards the run they were about to undertake, to enable comparisons to be made with a ‘post-run’ state. Participants were then required to run for one mile whilst providing input for the five word-pairs at regular intervals on the EmotiRun application. The design of EmotiRun involved audio cues to alert the participant as to when to provide this input (see section 5.2.2). Dependent on the allocated group the participant would either have been presented with the ‘emotional’ display or this would have been hidden. The author ran alongside the participant capturing additional data on factors that may have influenced the inputs, and to assist in avoiding any hazards that may have emerged during each individual run. The author also noted any comments made by the participants whilst interacting with the application.

Once the participant had reached the one mile point on the route they were requested to complete the interval for which they were providing input for, before pressing the stop button to end the current run. The participants were then asked to answer a short questionnaire to note their ‘post-run’ emotional state (see Appendix B.1.5), and reflect on how they felt the run went. After a brief cool down, to allow the participant to catch their breath, the same process was repeated (‘pre-run’ questionnaire, one mile run with application, ‘post-run’ questionnaire) with a second variation of EmotiRun.

Following the completion of both of the runs, participants were invited to provide general feedback on the study experience and the EmotiRun application. A debrief was then given.

6.2.5 Pilot Study

Alike to the initial field study, a pilot study was undertaken prior to the main user study to test the usability of EmotiRun in the required study settings. A key objective of the pilot was to ensure that the intervals were of a suitable length, enabling data to be collected regularly enough to provide a dynamic representation of a user’s emotional state, whilst not interfering too much with the given task of running. The pilot also aimed to understand whether the captured data was sufficient in allowing the study questions to be addressed.

For the pilot study a single runner was engaged, following a similar procedure as noted in section 6.2.4. However, the participant did not complete the running habits questionnaire as this had been previously validated in the initial user study (see section 3.1).

The functionality of EmotiRun, both with and without the ‘emotional’ display, worked as expected for the two runs undertaken. The necessity of headphones to hear the audio cues was confirmed, as it was found the outside setting of the study was somewhat noisy. It was additionally noted by the participant that the intervals seemed to be of an appropriate length, allowing a short period of rest from data entry between each interval, whilst still keeping them engaged and interacting with the application. Evaluation of the collected data suggested that the measures were sufficiently sensitive to detect potential differences in running with and without an ‘emotional’ display. This will be investigated further with the larger sample size of the main user study.

With the successful completion of the pilot, and the validation of the procedure specified in section 6.2.4, the main study may now commence.

6.3 Results

The following subsections provide the results from the main user study, in relation to the study questions posed in section 6.1. First, the five categories of self-report data are contrasted over the run intervals, i.e. at each 40 second sampling point. Secondly, a speculative analysis is performed on a potential difference in ratings at the start and end stage of a run. The meaning of these results will subsequently be examined in section 6.4, drawing on informal observations made by the author during the sessions.

Note that all results are presented to two significant figures. All the statistical tests within this section also use alpha level 0.05.

6.3.1 Effects of the 'Emotional' Display on Participants

The results presented in this subsection relate to study question one: *Are users' self-report ratings of the five presented word-pair dimensions influenced by the dynamic traffic light 'emotional' display of EmotiRun during a run?*

As described in the study procedure (see section 6.2.4), participants rated their feelings at regular intervals throughout their runs. A total of 24 ratings were collected from each participant on each separate word-pair, 12 per run. Each analysis thus makes use of 192 ratings (12 per run x 2 runs x 8 participants).

The mean rating for each participant was computed across the 12 intervals of each run, and the Student t-tests used to determine statistical significance (see Table 6.1).

Rating	**With Display** $\bar{x}$ (SD)	**Without Display** $\bar{x}$ (SD)	**T Value** *(to 2.d.p)*	**Sig**
Strong-to-Weak	3.3 (0.6)	3.4 (0.5)	0.41	.35
Happy-to-Sad	3.8 (0.4)	3.7 (0.5)	0.60	.28
Energetic-to-Tired	3.3 (0.4)	3.1 (0.6)	1.41	.10
Enthusiastic-to-Disinterested	3.7 (0.4)	3.4 (0.5)	1.82	.06
Relaxed-to-Nervous	3.9 (0.4)	3.7 (0.4)	1.95	.05*

Table 6.1: Means, Standard Deviations and Statistical Significance Contrasting Ratings With and Without 'Emotional' Display

Graphs shown in Figures 6.3 to 6.7 present the average ratings for all participants at each sampling interval, for each of the word-pairs. Each graph contrasts ratings with and without the 'emotional' display.

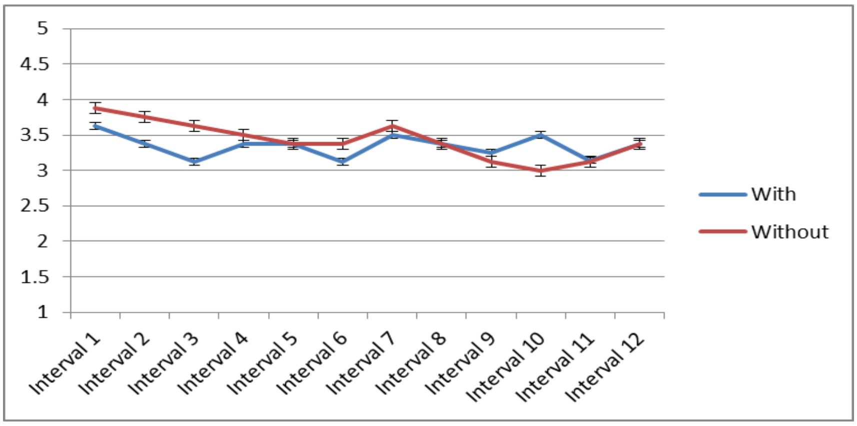

Figure 6.3: Main User Study Interval Graph – Strong-to-Weak

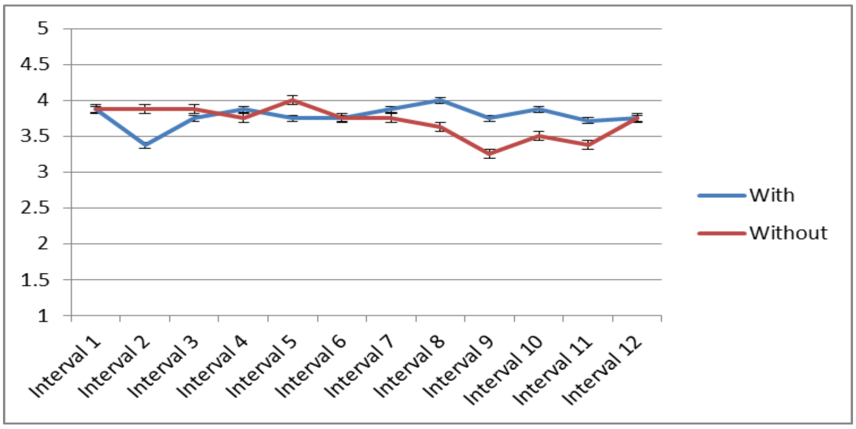

Figure 6.4: Main User Study Interval Graph – Happy-to-Sad

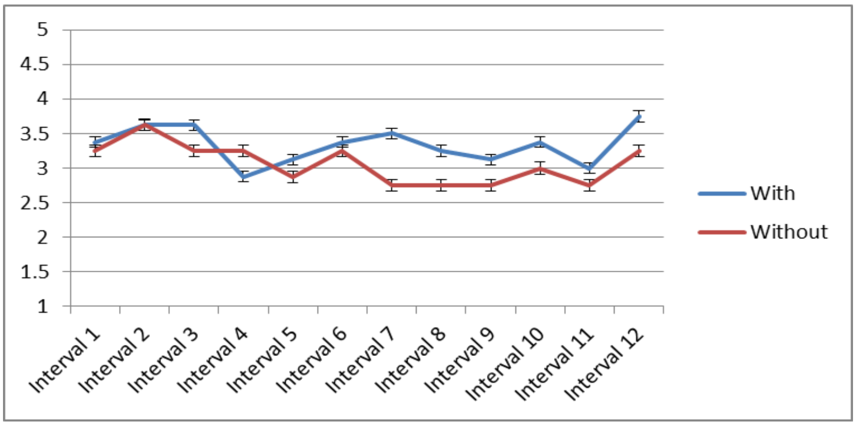

Figure 6.5: Main User Study Interval Graph – Energetic-to-Tired

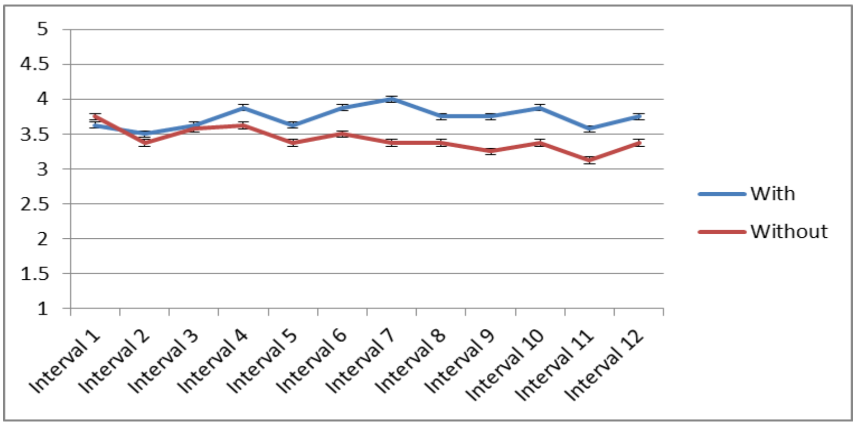

Figure 6.6: Main User Study Interval Graph – Enthusiastic-to-Disinterested

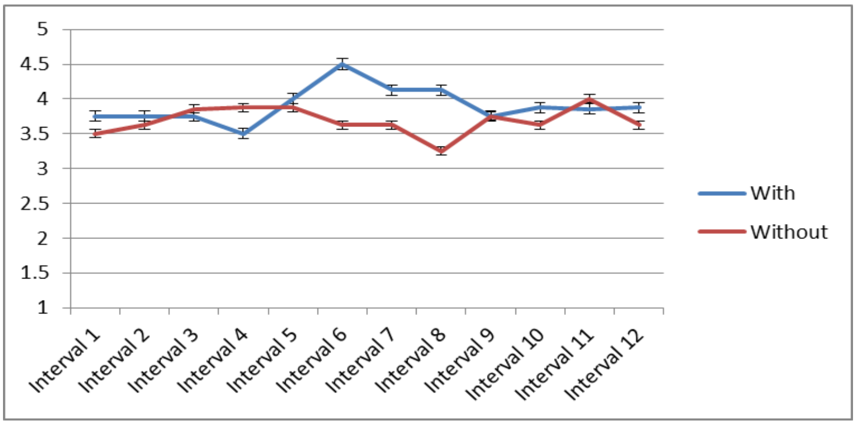

Figure 6.7: Main User Study Interval Graph – Relaxed-to-Nervous

Informal inspection of these graphs seemed to show differences in ratings for stages of a run. For example, Figure 6.7 shows a large deviation in the middle stage of a run with the 'emotional' display present.

6.3.2 Speculative Analysis of Running Stages

Reflecting on the data presented in the graphs above, it appears that there may have been a combined influence of the emotional display with the stage of run. To further examine this potential effect, a 2 x 2 repeated measures ANOVA (display x stage of run) was performed to contrast ratings made in the first four intervals of a run with the last four intervals of a run. Thus, the mean rating for each individual participant at the beginning and for the end of their runs were computed and treated as an observation in this analysis. This post-hoc analysis was carried out to contrast beginning and end stages of the runs for all five word-pairs. Each is reported below, alongside graphs presenting data from the beginning, middle and end stages of the run.

It is acknowledged that an ANOVA is not a conventional choice for this post-hoc analysis. However, Dr Watts advised that it may show some insights on possible interactions between self-report ratings and running stage. Although it would have been possible to contrast three phases, it was decided to use only the beginning and end stages as a more conservative approach to this post-hoc analysis.

Strong-to-Weak

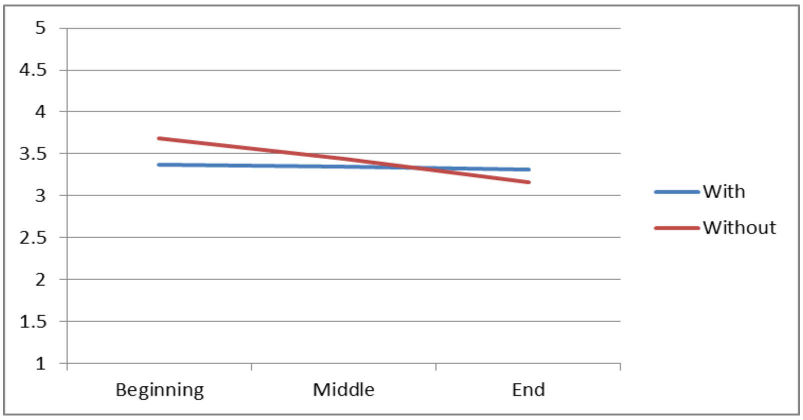

Figure 6.8: Main User Study Stage of Run Graph – Strong-to-Weak

The ANOVA for this word-pair did not show a significant difference in main effect for the display factor (F= 0.14 (7); p=.72).

The ANOVA also did not show a significant difference in main effect for the stage of run (F= 2.3 (7); p=.18). The mean ratings for the end of the run were 3.2 (SD 0.65) and were 3.5 (SD 0.59) for the beginning.

An interaction effect is evident in the ANOVA (F= 5.76 (7); p=.047). Runners consistently rated that they felt stronger at the end stage of their run when they were presented with the 'emotional' display (3.3, SD 0.77) than when they were without it (3.2, SD 0.53).

Happy-to-Sad

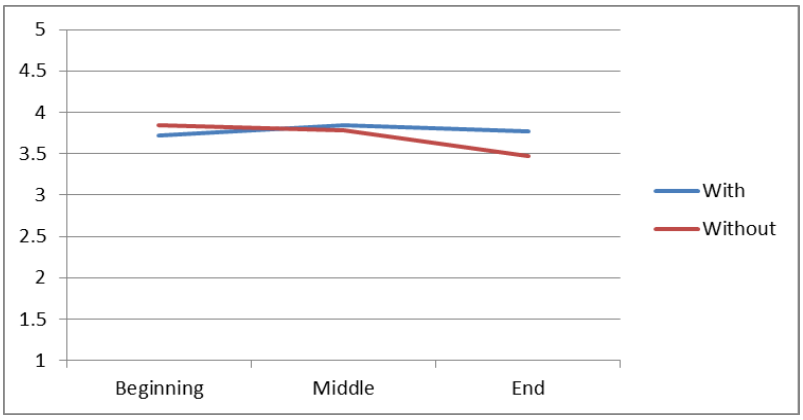

Figure 6.9: Main User Study Stage of Run Graph – Happy-to-Sad

The ANOVA did not show a significant difference in main effect for the display factor (F= 0.37 (7); p=.56) for the Happy-to-Sad word-pair.

The ANOVA did not show a significant difference in main effect for stage of run either (F= 1.1 (7); p=.32). The mean ratings for the end of the run were 3.6 (SD 0.47) and were 3.8 (SD 0.6) for the beginning.

Additionally, no significant difference in interaction effect (F= 2.5 (7); p=.16) was found.

Energetic-to-Tired

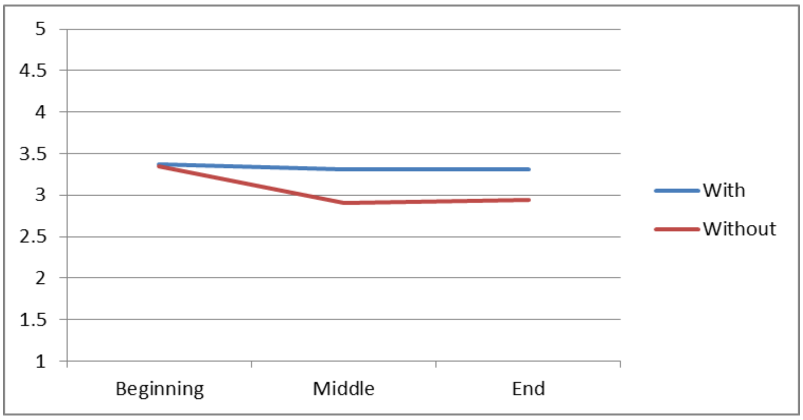

Figure 6.10: Main User Study Stage of Run Graph – Energetic-to-Tired

The ANOVA for the Energetic-to-Tired word-pair did not show a significant difference in main effect for the display factor (F= 1.2 (7); p=.31).

Also, no significant difference in main effect for the stage of run (F= 1.3 (7); p=.3) was found. The mean ratings for the end of the run were 3.1 (SD 0.71) and were 3.4 (SD 0.53) for the beginning.

The ANOVA did not show a significant difference in interaction effect (F= 1.9 (7); p=.21).

Enthusiastic-to-Disinterested

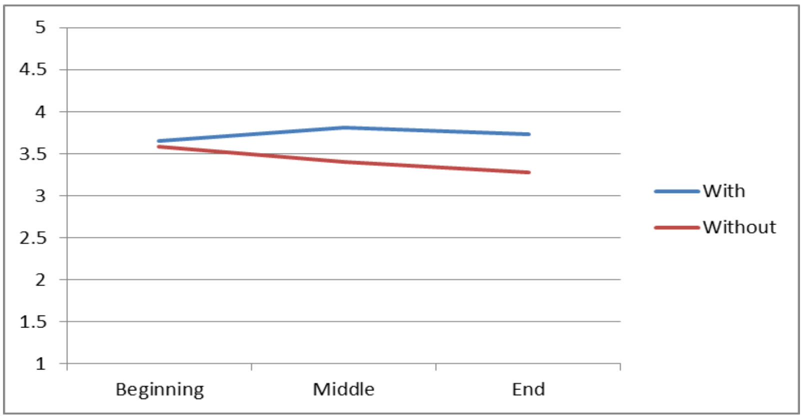

Figure 6.11: Main User Study Stage of Run Graph – Enthusiastic-to-Disinterested

The ANOVA did not show a significant difference in main effect for the display factor (F= 2.5; p=.16).

The ANOVA did not show a significant difference in main effect for stage of run (F= 0.24 (7); p=.64). The mean ratings for the end of the run were 3.5 (SD 0.55) and were 3.6 (SD 0.65) for the beginning.

The ANOVA did not show a significant difference in interaction effect (F= 2.9 (7); p=.13).

Relaxed-to-Nervous

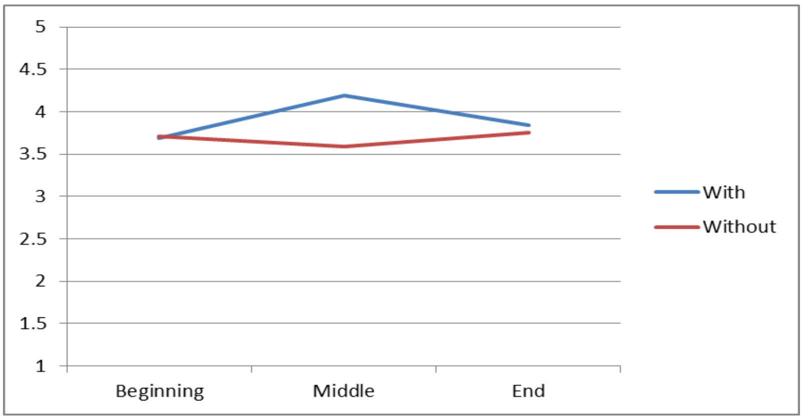

Figure 6.12: Main User Study Stage of Run Graph – Relaxed-to-Nervous

The ANOVA for the Relaxed-to-Nervous word-pair did not show a significant difference in main effect for the display factor (F= 0.15 (7); p=.71).

The ANOVA also did not show a significant difference in main effect for stage of run (F= 0.62 (7); p=.46). The mean ratings for the end of the run were 3.8 (SD 0.53) and were 3.7 (SD 0.41) for the beginning.

The ANOVA did not show a significant difference in interaction effect (F= 0.31 (7); p=.6).

6.3.3 Positivity 'Post-Run'

Having presented results of 'during-run' analyses, we now turn our attention to possible effects on feelings before and after a run. This subsection presents the results of the user study in relation to the second study question: *Do users view a run more positively 'post-run' as a result of being exposed to the dynamic representation of EmotiRun?*

Prior to each run, users were asked how they were feeling about the run they were about to undertake. After each run the same question was asked to reflect upon the run. Ratings were on a scale from 1 (negative) to 5 (positive); see graph below.

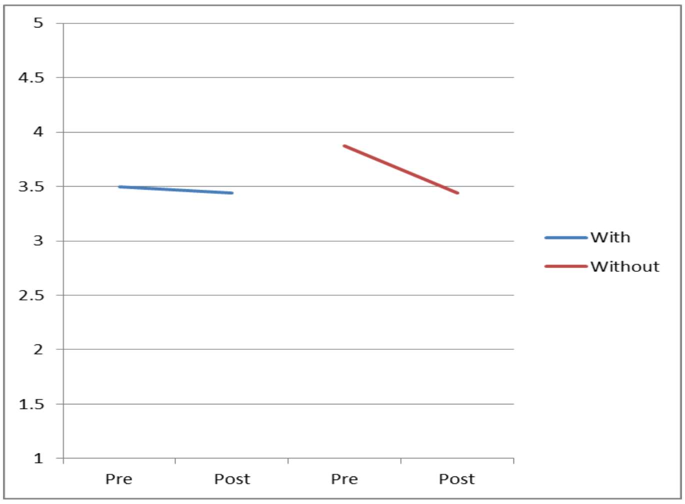

Figure 6.13: Feelings Towards the Runs – Pre- and Post-

Whereas ratings data for the 'during-run' analyses drew on a very large number of data points, pre- and post-run analyses were based on a small number of ratings. Thus, a Mann Whitney U test was used to contrast ratings pre- and post-run. This is a conservative non-parametric test that is appropriate for ordinal data, and was chosen for that reason. The second study question anticipates that runners will rate their activity more positively 'post-run' than 'pre-run' so a one-tail has been used.

With 'Emotional' Display

The Mann Whitney U test shows that there is no statistically significant difference between the two groups (U = 27, and the critical value of U at p < .05 is 15).

Without 'Emotional' Display

The Mann Whitney U test shows that there is no statistically significant difference between the two groups (U = 19.5, and the critical value of U at $p < .05$ is 15).

To provide context for the display conditions, how runners felt in themselves before and after a run was recorded, with ratings on a scale from 1 (negative) to 5 (positive). As discussed in the initial field study in Chapter 3, it was expected that runners would rate more positively 'post-run' than 'pre-run', shown in the graph below.

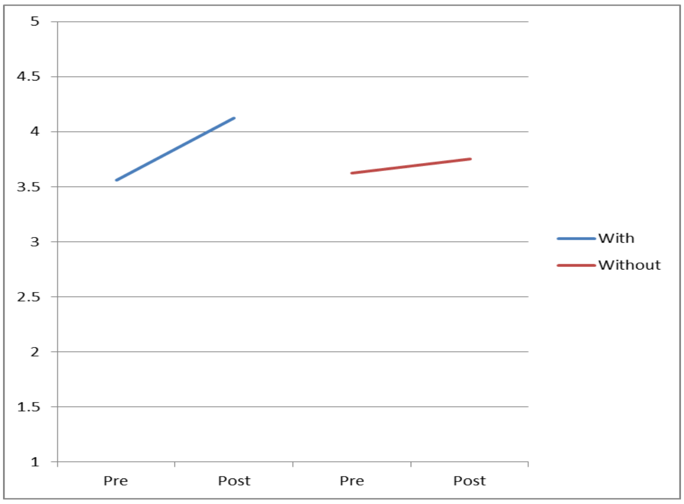

Figure 6.14: Feelings Right Now – Pre- and Post-

A Mann Whitney U test was again used to contrast ratings pre- and post-run.

With 'Emotional' Display

The Mann Whitney U test shows that there is no statistically significant difference between the two groups (U = 17.5, and the critical value of U at $p < .05$ is 15).

Without 'Emotional' Display

The Mann Whitney U test shows that there is no statistically significant difference between the two groups (U = 29.5, and the critical value of U at $p < .05$ is 15).

6.4 Analysis

With an overview of the study's results provided in the section above, the meaning of these can now be discussed in relation to the study questions. The work presented will subsequently be used in Chapter 7 to address the project-wide questions raised in section 3.3.

6.4.1 Implications for Study Questions

The first study question aimed to evaluate what effect, if any, presenting a user with a dynamic representation of their emotional state may have during a run. Overall, statistical analysis of each type of rating showed only one visible effect: ratings of relaxed-to-nervous pairs were marginally higher with the display than without. However, inspection of the intervals suggested that further analysis might show up differences in ratings only for particular stages of a run. There is a priori reason (see section 3.2.3) to suppose that beginning and ending stretches of a run have different personal significance for runners, so it is of particular interest to consider variations of user-provided ratings, in relation to the five word-pairs, for the start and end stages of a run. The results of the ANOVA tests revealed no significant difference for all but one of the word-pairs. The Strong-to-Weak word-pair reported an interaction effect, with runners rating that they felt stronger when presented with the 'emotional' display at the end stage of a run.

The second study question looked to explore whether the presentation of an 'emotional' display could cause a runner to have more positive feelings towards a run after its completion. Comparisons were made between pre- and post- states of runs, with and without a display present, using Mann Whitney U tests. The results for these revealed no statistically significant differences.

Whilst significant differences did not emerge from the results, reflecting on the graphs presented throughout the section it appears that an 'emotional' display may have had some effect on a runner, although the drivers of this are unclear. Thus, the remainder of this section discusses limitations of the data collection and statistics methodology, as well as reasons for this potential effect in relation to the posed study questions. Qualitative data captured during the running sessions is also drawn upon where appropriate.

6.4.2 Study Question One

Whilst there were limitations in the design, as discussed in section 6.4.5, and no other effects emerged from the results, graphs 6.3 to 6.7 appear to indicate that the presentation of an 'emotional' display could have had some effect on a user during a run. The Strong-to-Weak word-pair as noted earlier showed an interaction effect at the end stage of a run, with participants feeling stronger than in the beginning and middle phases. This could be attributed to a runner knowing they are soon to complete the run, with an awareness of how long it usually takes them to run a mile. As the average distance undertaken by users was typically 4.4 miles, the higher ratings in the end stage for this word-pair could also correlate to when they would normally be getting into their pace and strides. This was further reflected in the accelerated speed of the participants at this time, as recorded by the author.

Another word-pair of interest is that of Enthusiastic-to-Disinterested. Although no statistical difference was found in the tests, the graph displayed in Figure 6.11 suggests further investigation of variation with and without the display, particularly in the beginning phase of the run. The application itself could have acted as a strong cue for a user as they are more engaged in the run, required to think and provide input on how they are feeling, interacting with the device.

6.4.3 Study Question Two

The results of the tests for the second study question did not reveal statistical differences. In addition, the graph presented in Figure 6.13 shows little variation in the sentiment towards a run, with and without the 'emotional' display. It can therefore be concluded that the representation did not improve feelings towards a run immediately upon its completion. As discussed above, improvement of the follow-up questionnaire (see Appendix B.1.6), where users were requested to reflect on the runs undertaken, would have resulted in additional data that could have enabled better evaluation of the study question.

Another related point that was explored was how runners were feeling "right now" pre- and post- each run. The graph presented in Figure 6.14 is of interest as it may be seen that runners felt slightly better post-run with the display present. Whilst the Mann Whitney U tests did not show significance, this is deemed worthy of further exploration.

Of general note, to gain a deeper understanding of how users viewed the device, the shown representation and whether the inferences made were seen to be plausible they could have been asked for more specific feedback, rather than for general commentary, post-run.

6.4.4 Experiential Factors with the 'Emotional' Display

There is also evidence from the qualitative commentary, captured in relation to individual participants as they ran, and participant feedback that supports a possible effect with a display present. Four out of eight participants commented on the display, with one individual exclaiming "wow" at a green light appearing, and another who "saw the green as motivating". It may therefore be concluded that the representation could have been viewed as a form of motivational cue. Participants also appeared to miss the display when it was not present, if it was shown on the first run and hidden on the second, with a runner noting on the "second time I looked but it wasn't there".

The limitation presented by participants only using a subset of the scale, discussed in greater detail in section 6.4.5, resulted in the averages calculated fluctuating little, and therefore the representation was often unchanged across intervals. The participants were aware of this, noting at the end of the running session that the representations shown were "mostly the green and amber combination" and that the "lights didn't change much". If the application had been used by an individual runner over a period of time a more sophisticated affective model could have been developed, adjusting the representation based on the average inputs provided by the user.

6.4.5 Data Limitations

In evaluating the user study it is worth considering the validity of the statistics. Due to the study's complex design, with runners providing input for multiple runs at multiple intervals, compromises had to be made to organise the collected data into a form in which suitable tests could be applied. For each word-pair this resulted in condensing the data points for each interval to an average of all participants in that interval. A larger dataset may therefore have exposed more significant variations.

Sampling Interval

The study procedure, outlined in section 6.2.4, may have also had an impact on the collected results. Each running session consisted of two one mile runs, with a sampling interval of 40 seconds. The pilot study appeared to confirm the suitability of the interval, however many of the participants in the main study commented that the “timing between was too short” and that it was “hard to think” of responses due to the frequency. Users may therefore have not carefully considered their responses, nor reflected and compared how to score in comparison to how they felt in the previous interval. This is reflected in the collected results with most individuals only making use of the middle three buttons of the scale, with an average score across the study of 3.5. Future investigations could address this by conducting pilot studies with more participants to consolidate the length of the intervals. The given application could also have been designed to allow a user to specify their own intervals, a recommendation provided by one of the study participants. A further suggestion was to interval sample at set distances rather than set time periods.

Whilst some runners noted frustration at the frequency of the intervals this could have been because they were unfamiliar with thinking about their emotions during a run. If multiple running sessions had been carried out, whereby runners gained familiarity with the application, they may have been more aware as to how they were feeling, thus providing greater insights into their emotional state from which richer dynamic representations could be generated.

Route Characteristics

Another design decision that may have influenced the collected data is the terrain chosen for the running route. The route selected was mainly flat, with only one small section of incline, which may have accounted for the moderate ratings provided by the participants. If the terrain was hillier, and presented the runners with greater challenge, more negative ratings could have been captured. Increasing the distance of the running sessions may also have afforded larger variations with and without display usage, with runners feeling a greater need to rely on the EmotiRun application as they potentially tire and lack enthusiasm over the duration of the run.

Participant Profile

The general fitness of the participants could have also biased the dataset. Those within the sample were relatively fit, exercising an average of 3.3 times per week for one hour; engaging in strenuous activities such as hockey, circuits and dance. This is in addition to running activities, with participants usually undertaking 1.6 runs a week, each time covering 4.4 miles on average. The age of the sample may be considered an equally influencing factor, with all but one of the participants aged from 19 to 23. Of interest, the oldest runner used more of the scale values than all other participants, also recording the lowest average score over the study (2.9). Thus, in future studies greater exploration of the impact that age and fitness levels have on application usage may be of interest.

Questionnaire Construction

Furthermore, deliberate decisions were made as to the data collected. To capture information in relation to the second study question several short questionnaires were constructed. Whilst a potentially trivial point, if these had contained different questions, different results may have emerged. One such questionnaire (see Appendix B.1.6) was given to users five days after a run, with participants asked to reflect on the runs they had undertaken and review their current attitudes towards running. This was to be used to compare the pre-run state of an individual with their post-run state for each run. The author felt that it may be difficult for users to comment on the two runs separately, as they were undertaken in a single session, so participants were allowed to refer to the two runs collectively if required. As a result, the pre-run and post-run states with and without the 'emotional' display were unable to be distinguished and compared, which presented a slight limitation on the data collection.

EmotiRun Configurations

Different or additional word-pairs may also have yielded more insightful data. Whilst the word-pairs used were cross-validated with the PANAS scale (Watson, Clark, and Tellegen, 1988) and the initial user study, different words could have resulted in a great variation of responses from participants.

Another feature omitted from the results was the use of the 'weightings function', configured on the landing screen of the application, as discussed in section 5.2.2. The provided weightings impacted the computed averages and representations shown to users, allowing the application to be tailored to an individual. However, in the results section it did not figure to include these as it posed difficulty in comparing data between participants, and did not appear to have an effect worthy of investigation.

6.5 Conclusion

This chapter reported the design and findings of a study of runner self-report ratings to examine the potential interacting effects of an emotional display. No strong statistical effects were found. However, some intriguing patterns were in evidence in the 'during-run' data and qualitative evidence suggesting routes for further work. In the next chapter, these will be considered in the context of the project as a whole. Chapter 7 will also proceed to summarise and critique the entirety of the project, reflecting on the work undertaken.

Chapter 7

Conclusions

The previous chapter made use of the EmotiRun application, presented in Chapter 5, to begin to address the research questions posed in section 3.3. This chapter will aim to draw upon the findings of the main user study, and other aspects of the project, including its grounding in prior work, to provide conclusions for each of these questions. A general discussion and critique of the dissertation will be presented first, with contributions to Affective Computing and the wider Human Computer Interaction field highlighted. Suggestions of further work, extending the project findings, will then be proposed to conclude the chapter.

7.1 Discussion

The primary focus of the project was to explore what effect, if any, a dynamic representation of a user's emotional state may have on a user if presented during a run. The project started by analysing surrounding literature to gain a foundation of understanding of the different parts of the intended system. We first discussed emotions and their relation to the human body (Oatley and Jenkins, 1996), particularly the bias they afford cognitive processing (Forgas, 1991; Isen, 2008). The short duration of an emotion (Levenson, 1988) was also noted as an important characteristic in the context of physical exertion, contrasted with the longer periods associated with mood and sentiment. All three of these affective concepts were subsequently evaluated throughout the project: emotions were captured during the running sessions via the EmotiRun application, with mood and sentiment recorded in questionnaire responses pre- and post- each run.

Whilst the chapter acknowledged the influence of previous emotional states by habituation and excitation transfer (Brave and Nass, 2002), these concepts were not integrated into the design and implementation of EmotiRun; the limitations this may have afforded are discussed later.

Reflecting on the cognitive activities and physiological changes that emotions generate within the body, the review then looked to explore different computational tools that could capture emotional data. Self-reporting techniques, particularly questionnaires and Likert scales such as McNair, Lorr, and Droppleman's (1971) Profile of Mood States and Watson, Clark, and Tellegen's (1988) Positive And Negative Affect Schedule (PANAS), became a key focus of this research as were deemed less obtrusive than other mechanisms of detection.

Following this, different approaches to how the collected data could be modelled were investigated, with the componential theory (Brave and Nass, 2002; Oatley and Jenkins, 1996) and the dimensions of arousal and valence selected for use in the project. The perceived flexibility of this model and the simplicity of the chosen dimensions were key reasons for this decision.

The last part of the literature review proceeded to highlighted ways in which emotions have previously been represented dynamically. The use of light, and the work by Snyder et al. (2015), was of particular interest although it was recognised that the suitability of this representation in an outside setting would require further investigation. As a HCI project, the design possibilities offered by contexts of use are of key importance.

Despite the foundation of knowledge established in the literature survey the author felt that the relationship of these concepts to the given context of running had been somewhat overlooked. For this reason an initial field study, seen to be a turning point for the project, was carried out, which provided clarification of the project's objectives and scope. In addition, it helped to highlight potential forms the system could take by recording accessories currently worn by runners. Words that participants spoke aloud as they ran were also noted and analysed, subsequently used in the construction of the rating scale for the self-reporting mechanism of EmotiRun. However, the main benefit of this study was testing the study procedure, including the construction of questions, selection of participants and trialing a form of self-reporting whilst running. When the main study was carried out later in the project potential issues that could have arisen had already been addressed, and the familiarity of the process enabled the study to be set-up in limited time constraints.

The analysis of this initial study and the findings that emerged from the literature review were then used to define a set of research questions, providing greater focus for the following phases of the project:

Research Question 1: How could a user's emotional state be dynamically represented, for user interpretation, in an active setting?

Research Question 2: How could we collect data input from users in a non-obtrusive and non-invasive way, in an active setting?

Research Question 3: How might we use collected data to make inferences of a user's emotional state within a two-dimensional space of valence and arousal?

Research Question 4: Are users affected by emotional state representations displayed 'during-run'?

Research Question 5: Do users view a run more positively 'post-run' as a result of being exposed to representations of their emotional state?

The Central Proposition: Support for Reflection Influences User State

The core driver of these questions was the belief that an 'emotional' display may have an effect, positive or negative, on a user whilst running or post-run. This is believed to be a novel area of investigation for emotion tracking in the running context, with many fitness trackers only allowing users to reflect on their emotional state post-run, where accurate recall of all states and events over a run could be difficult. Questions one, two and three aimed to explore different features that would need to be implemented to create a system capable of capturing emotions and displaying generated inferences of emotional state in a non-invasive way. Whilst a multitude of fitness trackers are commercially available, the author is unaware of any that provide this functionality. The findings in relation to these questions are discussed later in this section.

To provide further clarification of the running process a storyboard was then created, helping to visualise the different points at which a user may interact with a created system, and the components that would be required to support these interactions. This enabled the contextualisation of the research questions posed, from which a set of high-level requirements were defined, which were intended to guide the construction of the system.

Capturing, Combining and Representing Self-Report Data for Reflection

Following this guidance the individual components were designed, featuring a self-reporting tool to capture emotional data, subsequently passed to an affective model, based upon the componential theory selected within the literature review. This model was rather simplistic; calculating the average of the data captured each interval. If a more sophisticated model had been implemented, particularly the inclusion of calculations to account for previous affective states as noted in the work of Zillmann (1991), it is possible that more significant differences may have emerged in the results.

The range of possible averages that could be generated by the model and the provided data were split into five sub-ranges, each of which correlated to a specific 'emotional' display light representation. The choice of only five different variations may also have afforded limitations in capturing the effect of the representation on an individual, particularly as it was noted that for some user study participants the representation changed little over the duration of the run.

The use of only one form of dynamic representation could be seen as a further limitation. The display itself may have influenced the extent to which a user was affected by it. Evaluating the use of different representations of an individual's emotional state may have provided more insight for the research questions raised, and thus should be considered in extension work. This work could potentially build upon the Arduino prototype discussed in section 5.1.

The high-level architecture diagram presented in Figure 4.2 also highlighted an additional control component, proposed to synchronise data flow between the different components. Due to the simplicity of the EmotiRun code this architecture was not strictly adhered to, as it was seen to be an unnecessary overhead.

Word-pairs and Meaningful Dimensions on Running

Another key focus of the design work was exploring the word-pairs to be used as part of the self-reporting tool. Whilst the selected words were cross-validated with words provided by participants in the initial study and items used on the PANAS and PANAS-X scales (Watson, Clark, and Tellegen, 1988; Watson and Clark, 1999), their use within a word-pair was not validated, particularly for use within a running context. Thus additional or different word-pairs may have revealed data of greater variation, providing more useful insights for the research questions posed. Notwithstanding, as the main user study appeared to indicate some effect with an 'emotional' display present, constructed from data captured in relation to the selected word-pairs, the rating scale may be seen as a valid contribution for further investigation of emotions whilst running.

Form Factor and Modes of Interaction

At this point it is worth highlighting that it was originally envisaged that the system would be a form of wearable technology, which is reflected throughout the design section, particularly in the presented low-fidelity prototypes of the user interface. Whilst exploration of these designs in the Arduino prototype was deemed useful in beginning to understand the type of system needed to address the research questions of the project, if a mobile application had been decided upon earlier more detailed designs could have been constructed. In turn, this may have resulted in a more sophisticated affective model being implemented and a more aesthetically pleasing interface.

With the foundations of a design established, the implementation of the system began. An initial prototype was built with an Arduino microcontroller, but due to multiple complex challenges it was abandoned, and a decision was made to create a mobile application instead. This application, named EmotiRun, was similar in design, thus most of the Arduino code was reused. The application consisted of two screens shown in Figure 5.2. The key feature was the self-reporting mechanism, whereby users provided input by pressing buttons on the screen at set intervals, in relation to the selected word-pairs. The dynamic representation reflected a traffic light system, implemented using inactive buttons as light icons.

Although this application enabled data to be captured that helped to address the research questions, it was not without its faults. The first issue was the overlapping of audio tracks if a user provided input before an audio cue had finished playing. Whilst this was a known bug, due to time constraints it was decided that users would be trained to account for this in their input actions. However the main flaw in the implementation was the email function, intended to send collected user data to the author. Due to poor Internet connectivity its functionality was temperamental, thus screenshots of the created emails were captured. This subsequently involved a large amount of manual data entry, which was very time consuming. As it was flagged in one of the first user studies it could have been resolved, but the author was reluctant to amend the code at the risk of introducing further defects. Notwithstanding, to the best of the author's knowledge such a tool has not been implemented before, where users interact with a device whilst partaking in physical activity.

Tailoring Meaning Through User-Specified Weightings

Also of note, whilst the 'weightings' function discussed in section 5.2.2 was implemented as a feature of EmotiRun its relevance was not seen in the collected data, and thus it was omitted from the results and analysis of the main user study. However, if the application was regularly used by a runner it could help tailor the technology to the individual, which has been found to be effective in changing attitudes and behaviours (Fogg, 2002).

Following the completion of the implementation a main user study was carried out. The study was designed to gain new knowledge that could be used to address the posed research questions in section 3.3. These questions were further refined in relation to the implemented application to provide more detailed focus for the study (see section 6.1). The study involved users completing a running habits questionnaire as well a set of 'pre-run' questions regarding their current emotional state, prior to undertaking a one mile run with one variation of EmotiRun ('emotional' display visible or hidden). Following a 'post-run' state questionnaire the process was then repeated for each participant with a second variation of the application. The distance was selected to enable enough data to be captured for each individual, whilst also enabling the author to run alongside the participant and take notes without tiring. If the system was used autonomously this distance could have potentially been increased and the impact of this investigated.

To test EmotiRun a pilot study was undertaken. Although no issues arose in this session it became evident in the main user study that certain features of the application, such as the length of the intervals, may have presented limitations in assessing the effect of the dynamic representation on a user, and thus would have benefited from further consideration. In particular it was noted that participants felt there was little time within intervals to consider their responses. A pilot study with more participants or using those involved in the main user study could have highlighted this, as noted in section 6.4.

The main user study was subsequently carried out with eight runner participants. Whilst the results of this study did not show significant differences with and without an 'emotional' display present, the participant comments during the runs and upon their completion indicate that users were interested in the dynamic representation, with some viewing it as a motivational cue. As the participants only used a subset of the scale buttons provided the representation frequently remained the same for long durations of the run. Increased granularity for the representations could have resulted in more insight on the extent to which a user was impacted by the presented inference of their emotional state.

7.2 General Conclusion

At this point we can now reflect on the objectives of the project, assessing how the findings presented relate to the research questions specified in section 3.3. This discussion begins by evaluating the implementation of EmotiRun in relation to the first, second and third questions, before reflecting on the effects of the dynamic representation and providing evidence for the fourth and fifth questions, the research focus of this project.

During the literature review in Chapter 2 it was suggested that an individual’s emotions could be captured using a self-reporting mechanism, deemed to be less obtrusive than other methods researched. Thus, a form of self-reporting was tested in the initial user study, and due to its success was integrated as a feature of the EmotiRun application. This mechanism made use of a set of word-pairs constructed specifically for use in this project, as discussed earlier. The data captured enabled inferences of an individual’s emotional state to be generated, mapping to a dynamic representation. The results and analysis of the main user study, presented in Chapter 6, indicated that the dynamic representation displayed to users had some effect, if only minor, on the ratings they provided. This method of data capture thus shows promise for use in further studies tracking emotions whilst running. On the other hand, to improve the design of this tool it would have been beneficial to carry out observational studies of runners interacting with a mobile application on a run, incorporating noted affordances into the design.

In relation to the third study question, limitations may have been presented by the simplicity of the affective model selected. The model may account for the minimal variations in the representation as the averages calculated were similar across the intervals. Whilst users were not probed for feedback on the perceived plausibility of the inferences, no participants noted that the emotional states represented differed from how they felt. Thus, there is potentially some promise for this model that could be investigated in further work.

The core part of the design however was the dynamic ‘emotional’ display; in relation to research question one. This display took the form of a traffic light system using three inactive buttons, coloured green, orange, and red, to represent the different lights. This subsequently afforded five different combinations that could be displayed to a user. The design was intended to be bold and simplistic to allow a user to easily interpret it whilst running along, and to be able to view it at a glance. A particular design choice was the use of static colours, as it was thought that varying the brightness of a light would be difficult to distinguish in the outside setting of the study. As discussed in the analysis of the main user study, in section 6.4, participants noted that the representation remained green and amber throughout most of the running session. It is thought that this impacted how much effect the representation had on a user, as the only participant comments captured during a session were in relation to the green light only being displayed. Thus, if more green or red light only combinations had been shown more may have emerged from the results.

Using EmotiRun a user study was undertaken to investigate research questions four and five. The findings of this study, as discussed in sections 6.3 and 6.4, showed that users are somewhat affected by emotional state representations displayed during a run, recording more positive ratings when presented with the affective display than without. However, as no significant differences emerged in the results further validation is required to support this. It is acknowledged that engaging more participants in more than one run with each variation of EmotiRun would be of benefit in future studies.

Due to the limitations presented by the study procedure in evaluating participant’s reflections on the runs undertaken, with a user’s sentiment towards a run only captured immediately upon its completion, the fifth research question was unable to be thoroughly addressed. Moreover, the graph presented in Figure 6.13 indicates that a runner’s sentiment towards a run does not vary significantly with or without an ‘emotional’ display present, thus further exploration of this question is not proposed.

7.3 Future Work

With the evaluation and critique of the project complete, we will conclude by presenting ideas for future work that may build upon the project and its findings. This section starts by suggesting further explorations with the current EmotiRun application, prior to outlining key areas of improvement in its implementation, and highlighting potential contributions to other applications and studies.

When designing the main user study many decisions were made as to the format of the running task to be undertaken, which may have afforded specific forms of interaction with the EmotiRun application. One such decision was the route and the mileage of the runs, as discussed in the study analysis in section 6.4. Taking into consideration the fitness level of the selected participants and the average mileage they usually undertake, the runs within the study may not have been perceived to be overly challenging, thus users may not have felt a need to use EmotiRun and become more aware of their emotional state. It is believed that more varied ratings may be recorded with a longer route and more undulating terrain, as a user is confronted with a greater physical challenge. This may therefore be considered of interest to investigate further.

A particular limitation of the main user study was the small number of participants engaged. Only eight runners completed the study, resulting in four participants in each group, as discussed in section 6.2. Whilst males and females were equally represented in the sample, the demographic was otherwise constrained, with all but one participant aged between 19 and 23, and picked from an opportunity pool of family members and university undergraduates. A secondary investigation with the current version of EmotiRun may therefore seek benefit in using a larger and more varied group, where there may be greater variation in provided ratings and subsequently more significant differences may emerge from the results. In addition, conducting a study with a participant group who display a wider range of running experience could reveal how different fitness levels use and are affected by EmotiRun and its dynamic representation. This insight could help further tailor the application to individual usage.

The time constraints of the project also shaped the design of the main user study, with participants only undertaking two short runs. As a result, the user only viewed the dynamic representation on a singular occasion. Thus it is considered of interest to evaluate the impact of using EmotiRun for multiple runs, over a longer period of time, where more significant shifts in a user’s attitudes towards running may be evident. This investigation could provide further evidence in which to address the fifth research question of this project.

Future work could also investigate the impact the dynamic representation has on a runner’s performance, analysing changes in statistics usually captured by fitness trackers. The most common statistics used by runners during and after a run were noted in the initial field study, shown in the spider diagram in Appendix A.1.3. Pace was seen to be of particular interest, with runners frequently monitoring it throughout a run to ensure consistency and reach specific time goals for set distances. Thus potential questions that could be deemed worthy of exploring are: Does an increase in pace result in more positive ratings? Does an individual run faster with an 'emotional' display present?

Whilst the current application could be used for further investigations it is also noted a number of improvements could be made to its performance. Improvements to the affective model and the dynamic representation have previously been discussed in sections 6.4 and earlier in this chapter, thus the suggestions below will focus on other aspects of the system.

One prominent feature that could be improved is the length of the intervals in which users are requested to provide ratings for the self-reporting mechanism, as discussed in section 6.4. Participant feedback reported that there was not enough time to think of responses for each word-pair, with little time to rest before the next interval started. Although the application could seek benefit from extending the interval length, it is also seen of interest to evaluate the impact of different intervals, varied by time or distance. These intervals could be pre-set before a study, tailored to an individual based on data from previous runs or selected by a runner.

Another feature of improvement is the scale provided for the self-reporting tool. As discussed in section 6.4, the average score recorded across the study was 3.5, with 86% of the inputs being a 3 or 4 rating. Only 13% of the ratings were either a 2 or a 5, and the 1 rating was not used at all during the study. Implementing a larger scale, possibly from 1 to 10, may therefore be considered. Whilst the highest and lowest numbers of the scale may still not be used it is likely to provide greater variations in the collected input. If implemented however, this would need to be thoroughly tested in a running context, as it may be too difficult to locate and press buttons if more are presented on a screen. Tailoring the scale, providing greater weighting on the buttons used less frequently, may also be beneficial, resulting in more distinct changes in the dynamic representation.

To further validate the self-reporting mechanism a physiological indicator of emotional state, a variety of which were explored in the literature review, could have been captured and compared to the ratings provided by participants. Of particular interest is monitoring the heart rate of an individual, as work by Anttonen and Surakka (2005) indicates that it may be possible to identify different responses to positive, neutral and negative stimuli. Heart rate tracking is also a key feature of many modern fitness devices, thus if the project's self-reporting tool was integrated with this technology it would be relatively easy to compare the two measurements. In turn, this could enable more informed inferences of an individual's emotional state to be made, potentially resulting in a more plausible dynamic representation.

As a final topic of discussion it is worth considering how the work of this project may be taken forward in future developments and research. One clear application would be to integrate the self-reporting feature into wearable fitness technologies. This would allow a user to track and view their performance and emotional state simultaneously. Such an application could also enable users to compete on their displayed positivity across a run, extending on the leaderboard functionality present in many running applications, namely RunKeeper and Strava. The data captured could also be sent to personal trainers and coaches to allow them to tailor running plans and training to an individual, particularly aware of points at which motivational cues may be needed. These motivational prompts could also be implemented in a mobile application.

Lastly, another research direction could be exploring the impact that presenting users with a false representation of their emotional state may have. This has previously been seen in the work of Matthews et al. (2015) with the MoodLight lighting system, as discussed in section 2.4. Therefore there is reason to believe that presenting a user with a more positive representation may result in them actually feeling more positive, and recording more positive ratings. In turn, this could lead to an individual being more motivated to engage in running. This also extends findings in the project where users specifically saw the green light of the 'emotional' display as motivational. Qualitative research methods are almost certainly required to engage more deeply with runner experience, as a stimulus for effective HCI design.

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Appendix A

User Study Documentation

A.1 Initial User Study

A.1.1 Study Brief

I am a final year Computer Science with Business student currently undertaking a dissertation under the supervision of Dr Leon Watts, Senior Lecturer in Computer Science (l.watts@bath.ac.uk). For my dissertation I am investigating whether physical activity, especially running, is affected by the way people feel. I am intending to build a system that processes some data (potentially heart rate, or self-inputted data) to create an 'emotional display'. I will then test my system to see whether this has any effect - good or bad - on runners who use it.

For example, a user wearing two sleeves will press buttons attached to one sleeve stating different emotions they may be feeling, the combination of these feelings will then be mapped to specific colour sets (i.e. red if unhappy, blue if happy) and on the opposite sleeve the corresponding light will be displayed. The intensity of the light shown can be changed to reflect the intensity of the emotion experienced.

This study will consist of three parts:

(1) **A 'pre-run' questionnaire:** exploring your engagement with running and exercise, including the details of your runs, the equipment you use, your feelings towards running and previous experiences. This questionnaire will also ask about your current feelings.

(2) **A ‘during-run’ interview:** I shall prompt you to speak aloud the way you are feeling whilst we run along together. More specifically, the brief for this part is as follows:

For this study we are going to go on a 1.5 mile flat run. I will be running alongside you and every 40 seconds will ask you how you feel. I would like you to say whatever comes to your mind first - a word or phrase. I will record this information on my mobile phone as accurately as possible and will check it with you afterwards.

(3) A 'post-run' questionnaire: assessing your feelings post-run.

The study is expected to take approximately 45 minutes - 20 minutes for part 1, 15-20 minutes for part 2, and 10 minutes for part 3. Also to note; you are able to withdraw from this study at any time.

If you have any questions after the study please get in touch on had23@bath.ac.uk.

A.1.2 Ethics Checklist

1. **Have you prepared a briefing script for volunteers?**

   Potential user study participants will be sent a link to a web form with a briefing script. They will be able to read this before agreeing to sign up to the study. On the day of the study, before it commences, this briefing script will again be presented.

2. **Will the participants be using any non-standard hardware?**

   No.

3. **Is there any intentional deception of the participants?**

   No.

4. **How will participants voluntarily give consent?**

   Potential participants will be sent a link to a web form with a briefing script. At the end of this script participants are asked if they wish to partake in the study. This question will be raised again with the participants before the commencement of the study. Participants will only answer questions and engage in activities once this consent has been obtained.

5. **Will the participants be exposed to any risks greater than those encountered in their normal work life?**

   Participants will be required to undertake a one and a half mile run on flat terrain. All participants that are recruited will be asked to confirm that they have already undertaken this mileage within the past month, thus minimising any physical risks. Participants will also be asked to communicate any injuries prior to the commencement of the study.

6. **Are you offering any incentive to the participants?**

   Yes. Participants will be offered tea/coffee and biscuits on completion of the study.

7. **Are any of your participants under the age of 16?**

   No.

8. **Do any of your participants have an impairment that will limit their understanding or communication?**

   No.

9. **Are you in a position of authority or influence over any of your participants?**

   No.

10. **Will the participants be informed that they could withdraw at any time?**

    Potential user study participants will be sent a link to a web form with a briefing script, which includes a statement specifying that they may withdraw at any time. This briefing script is also repeated before the commencement of the study. The right to withdraw is further highlighted to participants prior to the start of each part of the study.

11. **Will the participants be informed of your contact details?**

    Yes.

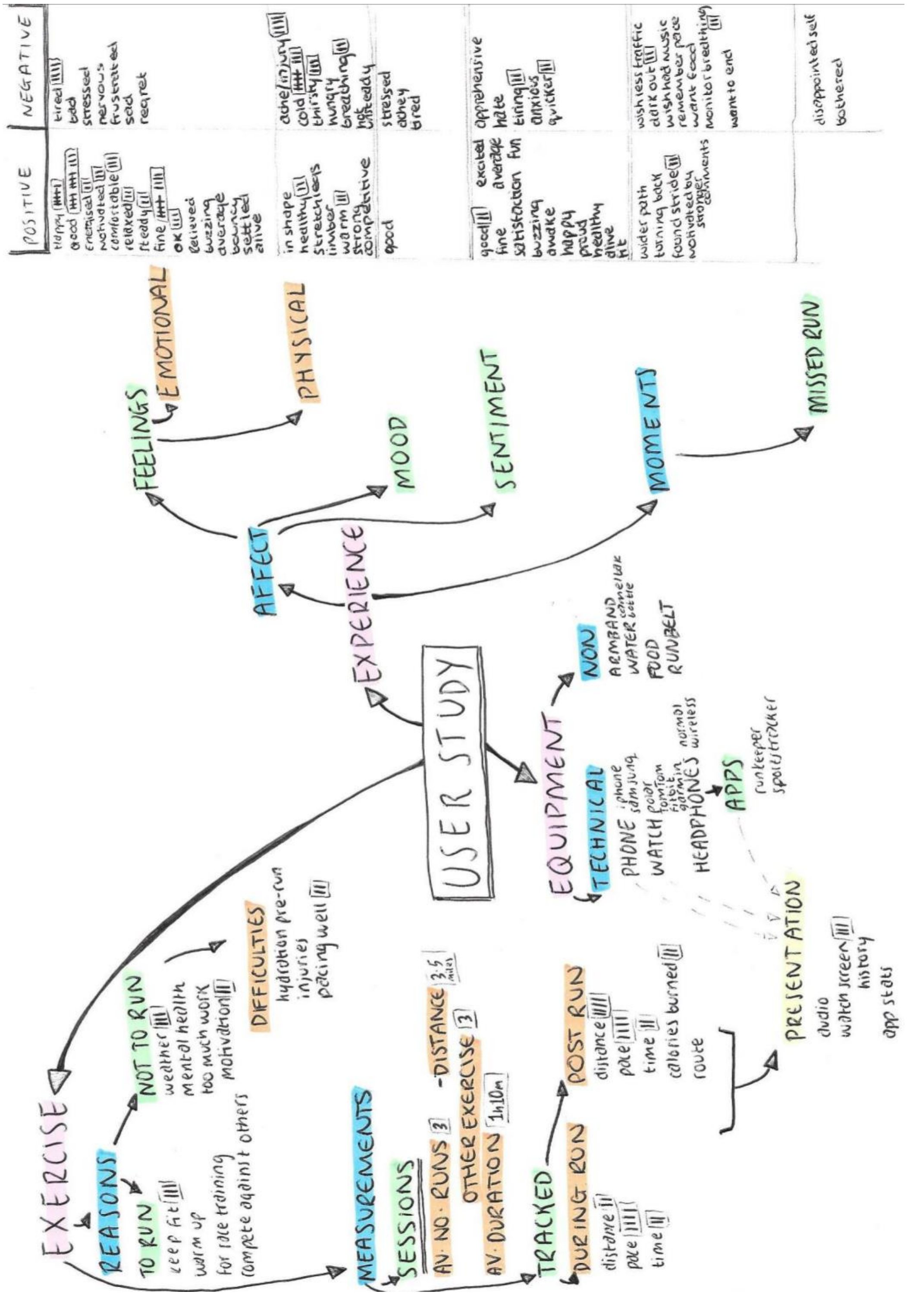
12. **Will participants be de-briefed?**

    Following the completion of the study participants will be informed that their results are available for viewing, particularly those captured during part two of the study. Participants will be reminded of the aims of the study and invited to ask any further questions. They will also be asked if they wish to partake in future studies. An additional reminder that they may withdraw or change their study data will also be given.

13. **Will the data collected from the participants be stored in an anonymous form?**

    Each participant of the study will be designated a numerical identification number, for reference throughout the results and analysis. The names of participants will not be stored alongside the numerical identification number but the mapping between will be remembered in case a participant wishes to view, change or withdraw their data at a later date. Email addresses will be stored for contacting participants in relation to the study and potential participation in future studies.

A.1.3 Spider Diagram



A.2 Main User Study

A.2.1 Study Brief

I am a final year Computer Science with Business student currently undertaking a dissertation under the supervision of Dr Leon Watts, Senior Lecturer in Computer Science (l.watts@bath.ac.uk). For my dissertation I am investigating whether physical activity, especially running, is affected by the way people feel. To explore this I have built a mobile application that collects self-reported data and processes this to create an 'emotional display'. The information collected will be used to evaluate whether presenting a runner with this 'emotional display' has any effect - good or bad - on their attitudes towards running.

This study will consist of one session, split into 8 parts:

(1) **This form:** to obtain your consent for partaking in the study. *[COMPLETED ONLINE PRIOR TO SESSION DATE]* {5 minutes}

(2) **A running habits questionnaire:** exploring your engagement with running and exercise, including the details of your runs, your feelings towards running and previous experiences. *[COMPLETED ONLINE PRIOR TO SESSION DATE]* {10 minutes}

(3) **Training:** to understand how to use the application that will be carried during the following section of the session. *[PRIOR TO SESSION START]* {5 minutes}

(4) **A run:** During this section you will be asked to undertake a 1 mile run along a specified route. On this run you will be asked to input data into a mobile application at 40 second intervals. The application will prompt you with what input is required. The training provided should ensure that you are familiar with how to use the application. On this run you will not be presented with one version of the application. Upon completion of the session your data will be stored for analysis. {8 ~ 12 minutes}

(5) **A 'post-run' questionnaire:** assessing your feelings post-run. {5 minutes}

(6) **A run:** after a short cool down, to catch your breath, you will be asked to undertake another 1 mile run along a specified route. Alike to the first run, you will be asked to input data into a mobile application at 40 second intervals. The application will again prompt you with what input is required. On this run you will be presented with a different version of the system. Upon completion of the session your data will be stored for analysis. {8 ~ 12 minutes}

(7) **A 'post-run' questionnaire:** assessing your feelings post-run. *[COMPLETED IMMEDIATELY POST RUN]* {5 minutes}

(8) **A 'post-run-delayed' questionnaire:** assessing your feelings towards the runs a few days later, after reflection. *[COMPLETED 5 DAYS POST SESSION DATE]* {5 minutes}

This session is expected to take approximately 45 minutes in person, and 20 minutes online. Parts 3, 4, 5, 6 and 7 will be carried out in person, the rest will be forms to complete online. Also to note; you are able to withdraw from this study at any time.

If you have any questions after the study please get in touch on had23@bath.ac.uk.

A.2.2 Ethics Checklist

1. **Have you prepared a briefing script for volunteers?**

   Potential user study participants will be sent a link to a web form with a briefing script. They will be able to read this before agreeing to sign up to the study. On the day of the study, before it commences, this briefing script will again be presented.

2. **Will the participants be using any non-standard hardware?**

   No.

3. **Is there any intentional deception of the participants?**

   No.

4. **How will participants voluntarily give consent?**

   Potential participants will be sent a link to a web form with a briefing script. At the end of this script participants are asked if they wish to partake in the study. This question will be raised again with the participants before the commencement of the study. Participants will only answer questions and engage in activities once this consent has been obtained.

5. **Will the participants be exposed to any risks greater than those encountered in their normal work life?**

   Participants will be required to undertake two one mile runs. All participants that are recruited will be asked to confirm that they have already undertaken this mileage within the past month, thus minimising any physical risks. Participants will also be asked to communicate any injuries prior to the commencement of the study.

6. **Are you offering any incentive to the participants?**

   No.

7. **Are any of your participants under the age of 16?**

   No.

8. **Do any of your participants have an impairment that will limit their understanding or communication?**

   No.

9. **Are you in a position of authority or influence over any of your participants?**

   No.

10. Will the participants be informed that they could withdraw at any time?

Potential user study participants will be sent a link to a web form with a briefing script, which includes a statement specifying that they may withdraw at any time. This briefing script is also repeated before the commencement of the study. The right to withdraw is further highlighted to participants prior to the start of each part of the study.

11. Will the participants be informed of your contact details?

Yes.

12. Will participants be de-briefed?

Following the completion of the study participants will be informed that their results are available for viewing. Participants will be reminded of the aims of the study and invited to ask any further questions. An additional reminder that they may withdraw or change their study data will also be given.

13. Will the data collected from the participants be stored in an anonymous form?

Each participant of the study will be designated a numerical identification number, for reference throughout the results and analysis. The names of participants will not be stored alongside the numerical identification number but the mapping between will be remembered in case a participant wishes to view, change or withdraw their data at a later date.

Appendix B

Questionnaires

B.1 Main User Study

This section lists the questions presented to each participant as part of the main user study.

B.1.1 Consent Form

1. Your name

2. Are you able to run 2 miles comfortably (with a rest in-between)?

3. Do you have any injuries? If so, what?

4. Do you consent to participating in this user study and accepting any potential risks?

B.1.2 Running Habits Questionnaire

1. Your name

2. What is your age?

3. How many times a week do you run?

4. What is the average distance you run?

5. What is the furthest distance you have run?

6. What is your average pace (in minutes per mile)?

7. If you partake in other exercise, what exercise do you do?

8. How many times a week?

9. How long each session?

10. If you are training for a race or towards a goal, what is this?

11. If you are training for a race or towards a goal, do you have a training plan?

12. How does running make you feel?

13. Is there anything you find particularly difficult when preparing for a run?

14. Is there anything you find particularly difficult when running?

15. When was the last run you can remember?

16. How far was it in miles?

17. How did it make you feel?

B.1.3 'Pre-Run' One Questionnaire

1. How do you feel generally today?

2. How do you feel generally today? (on a scale of negative {1} to positive {5})

3. How do you feel right now?

4. How do you feel right now? (on a scale of negative {1} to positive {5})

5. How do you generally feel about running right now?

6. How do you generally feel about running right now? (on a scale of negative {1} to positive {5})

7. How do you feel about the run?

8. How do you feel about the run? (on a scale of negative {1} to positive {5})

B.1.4 'Pre-Run' Two Questionnaire

1. How do you feel right now?

2. How do you feel right now? (on a scale of negative {1} to positive {5})

3. How do you feel about the run?

4. How do you feel about the run? (on a scale of negative {1} to positive {5})

B.1.5 'Post-Run' Questionnaire

This questionnaire was asked to participants post- both runs undertaken for the main user study.

1. How do you feel right now?

2. How do you feel right now? (on a scale of negative {1} to positive {5})

3. How do you feel about the run?

4. How do you feel about the run? (on a scale of negative {1} to positive {5})

B.1.6 'Post-Run-Delayed' Questionnaire

Participants were sent this online questionnaire five days after their running session, to reflect upon the runs and their attitudes towards running.

1. How do you feel the runs went?

2. How do you feel the runs went? (on a scale of negative {1} to positive {5})

3. How do you generally feel about running right now?

4. How do you generally feel about running right now? (on a scale of negative {1} to positive {5})

Appendix C

Raw Results Output

C.1 Initial User Study

C.1.1 Session Data

The raw data captured for the three parts of each session of the initial user study can be found below.

Participant 1

1.1 What is your age?

18 - 25

1.2 How many times a week do you run?

3

1.3 What is the average distance you run?

4 miles

1.4 What is the furthest distance you have run?

Half marathon

1.5 What is your average pace?

8:30 min / mile

1.6 Do you partake in any other exercise?

Yes

1.6.1 If yes, what exercise?

Hockey, pole, gymnastics

1.6.2 How long for?

1.5 hours, 1.5 hours, 1.5 hours

1.6.3 How many times a week?

2, 2, 1

1.7 Why do you run?

Keep fit

1.8 Are you training for a race or towards a goal?

No

1.8.1 If yes, what?

N/A

1.8.2 If yes, do you have a training plan?

N/A

1.9 How does running make you feel?

Good about myself and tired (short term)

1.10 Is there anything you find particularly difficult when preparing for a run?

Hydration (don't drink enough - particularly on long runs)

1.11 Is there anything you find particularly difficult when running?

Weak knees - it hurts, minor to relative painful. Causes short term walking during run

1.12 What equipment or accessories, if any, do you use whilst running?

Phone (iPhone), headphone (apple phones), armband

1.13 If you use tracking equipment, do you check/track any statistics during a run?

Yes

1.13.1 If yes, what?

Run keeper, distance and average pace, time

1.13.2 If yes, how is this information presented to you?

Audio

1.14 If you use tracking equipment, do you check/track any statistics post run?

Yes

1.14.1 If yes, what?

Distance, time, mile splits, pace chart

1.14.2 If yes, how is this information presented to you?

Runkeeper app

1.15 What runs do you typically do?

Easy

1.16 What type of route do you typically take?

Flat, Circular

1.17 When was the last run you can remember?

End of September

1.18 How far was it?

4 miles

1.19 How did it make you feel?

Unfit - after summer off of running

1.20 Have you intended to go on a run but missed it?

No

1.20.1 If yes, what was the reason for missing it?

N/A

1.20.2 How did you feel about missing it?

N/A

1.21 How do you feel generally today?

Well - bit stressed about university work

1.22 How do you feel right now?

Good

1.23 Are you ready for your run today?

Yes

1.24 How do you feel about the run?

A bit apprehensive

2.1 Feelings captured

Nervous
Wish less traffic
More settled
Good
A bit stiff
Frustrated

Happier path wider
Comfortable
Good
Sad because dark
Competitive
Regret not running more
Feel tired
Stressed about work
Bad about fitness
Good about being out
Thirsty
Wish I had music

3.1 How do you feel right now?

Good - bit tired

3.2 How do you feel about the run?

Could have been better - bit faster, felt uncomfortable for pace it was

3.3 Were there any particularly memorable moments on the run?

The music from car going past, time to turn back - kick as know on way back

Participant 2

1.1 What is your age?

18 - 25

1.2 How many times a week do you run?

5 – on treadmill

1.3 What is the average distance you run?

1.5 miles

1.4 What is the furthest distance you have run?

5 miles

1.5 What is your average pace?

17 km / hour for sprints

1.6 Do you partake in any other exercise?

Yes

1.6.1 If yes, what exercise?

Gym workout - Anna Victoria

1.6.2 How long for?

45 minutes

1.6.3 How many times a week?

5 or 6

1.7 Why do you run?

To warm up for gym workouts and to get heart rate up

1.8 Are you training for a race or towards a goal?

No

1.8.1 If yes, what?

N/A

1.8.2 If yes, do you have a training plan?

N/A

1.9 How does running make you feel?

I hate it but afterwards I feel fine/satisfaction

1.10 Is there anything you find particularly difficult when preparing for a run?

Motivation to go

1.11 Is there anything you find particularly difficult when running?

Pacing - always run too fast on my own

1.12 What equipment or accessories, if any, do you use whilst running?

Phone (iPhone), wireless headphones, Polar A300

1.13 If you use tracking equipment, do you check/track any statistics during a run?

Yes

1.13.1 If yes, what?

How long running for

1.13.2 If yes, how is this information presented to you?

On watch

1.14 If you use tracking equipment, do you check/track any statistics post run?

No

1.14.1 If yes, what?

N/A

1.14.2 If yes, how is this information presented to you?

N/A

1.15 What runs do you typically do?

Intervals

1.16 What type of route do you typically take?

Flat, One way

1.17 When was the last run you can remember?

Thursday 8th December, morning

1.18 How far was it?

1 mile

1.19 How did it make you feel?

Felt tired and hungry, and made me feel more tired

1.20 Have you intended to go on a run but missed it?

No

1.20.1 If yes, what was the reason for missing it?

N/A

1.20.2 How did you feel about missing it?

N/A

1.21 How do you feel generally today?

Okay - body aches from gym the other day

1.22 How do you feel right now?

Hungry

1.23 Are you ready for your run today?

Yes

1.24 How do you feel about the run?

I hate running

2.1 Feelings captured

Need to remember to pace
Ok
Err fine
Err yea
Feet, toes cold
Feet still cold
Erm fine
Dependent on how long we have left

Left hand is cold
Need to monitor breathing
Erm fine
Yea fine
Want some water
Fine
That I want a McDonald's
Yea fine
Yea fine
Tired
So want this to end

3.1 How do you feel right now?

Relieved

3.2 How do you feel about the run?

Yea, probably could have been quicker

3.3 Were there any particularly memorable moments on the run?

Passing McDonald's - the smell

Participant 3

1.1 What is your age?

18 - 25

1.2 How many times a week do you run?

2

1.3 What is the average distance you run?

7 km

1.4 What is the furthest distance you have run?

Half marathon

1.5 What is your average pace?

6:30 min / km

1.6 Do you partake in any other exercise?

Yes

1.6.1 If yes, what exercise?

Pole, home

1.6.2 How long for?

1.5 hours, 45 minutes

1.6.3 How many times a week?

2, 1

1.7 Why do you run?

For fitness and race

1.8 Are you training for a race or towards a goal?

Yes

1.8.1 If yes, what?

Bath half marathon

1.8.2 If yes, do you have a training plan?

No

1.9 How does running make you feel?

Tired, happy, proud

1.10 Is there anything you find particularly difficult when preparing for a run?

Motivation

1.11 Is there anything you find particularly difficult when running?

Staying at a similar pace

1.12 What equipment or accessories, if any, do you use whilst running?

Sometimes fit bit, water over 10km, phone with music and apple headphones in running belt

1.13 If you use tracking equipment, do you check/track any statistics during a run?

Yes

1.13.1 If yes, what?

Phone - average pace, overall, current km

1.13.2 If yes, how is this information presented to you?

Audio

1.14 If you use tracking equipment, do you check/track any statistics post run?

Yes

1.14.1 If yes, what?

Distance, number of steps, pace, calories burned, route

1.14.2 If yes, how is this information presented to you?

SportsTracker app - diary with stats

1.15 What runs do you typically do?

Easy

1.16 What type of route do you typically take?

Flat, Out and back

1.17 When was the last run you can remember?

Friday 2nd December

1.18 How far was it?

1 mile

1.19 How did it make you feel?

Decent

1.20 Have you intended to go on a run but missed it?

Yes

1.20.1 If yes, what was the reason for missing it?

The rain, shin splints or too much work

1.20.2 How did you feel about missing it?

A little bit bothered but not that the world is going to end

1.21 How do you feel generally today?

Tired

1.22 How do you feel right now?

Happy

1.23 Are you ready for your run today?

Yes

1.24 How do you feel about the run?

Average

2.1 Feelings captured

Chilly
Comfortable
Warmed up
Motivated
Boobs ache
Unsteady - pace changing
Hot
Surprised with comfort at speed

Happy
Chill - relaxed
Bouncy - springy
Steady
Like I should run more often
Left ankle a bit tired
Energised
Good
Motivated again
Overthinking breathing which messes me up
Motivated by random stranger comment
Steady
A little bit tired
Average
Pretty relaxed

3.1 How do you feel right now?

Really good - quite relaxed

3.2 How do you feel about the run?

Good - know shorter than normal distance so ran faster and feel better

3.3 Were there any particularly memorable moments on the run?

Random guy saying 'well done girls'

Participant 4

1.1 What is your age?

18 - 25

1.2 How many times a week do you run?

2

1.3 What is the average distance you run?

5 miles

1.4 What is the furthest distance you have run?

26.2 miles

1.5 What is your average pace?

5 min / km

1.6 Do you partake in any other exercise?

Yes

1.6.1 If yes, what exercise?

Pole

1.6.2 How long for?

1.5 hours

1.6.3 How many times a week?

1

1.7 Why do you run?

Because my fiancé is fitter than me

1.8 Are you training for a race or towards a goal?

Yes

1.8.1 If yes, what?

Bath half marathon

1.8.2 If yes, do you have a training plan?

No

1.9 How does running make you feel?

Buzzing, wakes you up

1.10 Is there anything you find particularly difficult when preparing for a run?

Within myself to go out when it is cold

1.11 Is there anything you find particularly difficult when running?

No

1.12 What equipment or accessories, if any, do you use whilst running?

Running watch - TomTom, normal headphones, Samsung phone, hydration camelbak, jelly babies

1.13 If you use tracking equipment, do you check/track any statistics during a run?

Yes

1.13.1 If yes, what?

Pace

1.13.2 If yes, how is this information presented to you?

Shown on watch

1.14 If you use tracking equipment, do you check/track any statistics post run?

Yes

1.14.1 If yes, what?

Distance and time

1.14.2 If yes, how is this information presented to you?

On the watch screen

1.15 What runs do you typically do?

Easy

1.16 What type of route do you typically take?

Flat, Circular

1.17 When was the last run you can remember?

Tuesday 6th December

1.18 How far was it?

10 km

1.19 How did it make you feel?

Woke me up and motivated me, felt muddy

1.20 Have you intended to go on a run but missed it?

Yes

1.20.1 If yes, what was the reason for missing it?

Intrusive depression

1.20.2 How did you feel about missing it?

A bit disappointed in myself

1.21 How do you feel generally today?

Better than normal

1.22 How do you feel right now?

Apprehensive about the run

1.23 Are you ready for your run today?

Yes

1.24 How do you feel about the run?

Excited haven't run in a while

2.1 Feelings captured

Happy to be stretching my legs
Limber
Happy and bouncy

Happy
Energised
Very glad I came
Need to remember charity shop
Having a workout
Quite strong
Very happy
Alive
Tiring slightly
Lungs are a bit tight
Thirsty
Feeling happier
Feeling in shape
Healthy
Healthy

3.1 How do you feel right now?

Buzzing

3.2 How do you feel about the run?

Fun, could have been longer

3.3 Were there any particularly memorable moments on the run?

After first 3 minutes found stride, haven't in a while and felt good

Participant 5

1.1 What is your age?

51 - 60

1.2 How many times a week do you run?

2

1.3 What is the average distance you run?

3 miles

1.4 What is the furthest distance you have run?

27 miles

1.5 What is your average pace?

9 min / mile

1.6 Do you partake in any other exercise?

Yes

1.6.1 If yes, what exercise?

Gardening, DIY

1.6.2 How long for?

1 hour

1.6.3 How many times a week?

2

1.7 Why do you run?

To keep fit

1.8 Are you training for a race or towards a goal?

No

1.8.1 If yes, what?

N/A

1.8.2 If yes, do you have a training plan?

N/A

1.9 How does running make you feel?

Healthy, alive, fit

1.10 Is there anything you find particularly difficult when preparing for a run?

Going out on cold nights

1.11 Is there anything you find particularly difficult when running?

No

1.12 What equipment or accessories, if any, do you use whilst running?

GPS watch (Garmin), Lucozade Sport on longer runs

1.13 If you use tracking equipment, do you check/track any statistics during a run?

Yes

1.13.1 If yes, what?

Pace and distance

1.13.2 If yes, how is this information presented to you?

Shown on watch screen

1.14 If you use tracking equipment, do you check/track any statistics post run?

Yes

1.14.1 If yes, what?

Calories burned, average pace overall and distance

1.14.2 If yes, how is this information presented to you?

On the watch history

1.15 What runs do you typically do?

Easy

1.16 What type of route do you typically take?

Flat, Circular

1.17 When was the last run you can remember?

A week ago

1.18 How far was it?

3 miles

1.19 How did it make you feel?

Exhausted - did it with someone else running much faster pace

1.20 Have you intended to go on a run but missed it?

No

1.20.1 If yes, what was the reason for missing it?

N/A

1.20.2 How did you feel about missing it?

N/A

1.21 How do you feel generally today?

Damp - cleaning cars

1.22 How do you feel right now?

Cold

1.23 Are you ready for your run today?

Yes

1.24 How do you feel about the run?

Anxious – it’s cold

2.1 Feelings captured

Okay
Warming up
Heads cold
Shin splint right leg
Good
Chilly top half

Shin splint gone
Good
Good
Okay
Pain in right sole
Warm
Out of breath uphill
Cold top warm legs
In a rhythm
On track
Good
No aches
Good
Could go further
Good

3.1 How do you feel right now?

Fine

3.2 How do you feel about the run?

Went well - right pace

3.3 Were there any particularly memorable moments on the run?

Running down a road in the dark

C.2 Main User Study

C.2.1 Session Data

The participant data recorded in relation to the questionnaires noted in Appendix B.1 may be found in the ‘StudyData’ Excel file within the uploaded project directory, on the ‘Questionnaire data’ tab. This file also contains the interval data recorded for each individual, located on the ‘Interval data’ tab. The remaining sheets within this file were used for the calculations and tests presented in the main user study results in section 6.3.

Appendix D

Code

D.1 Arduino

The code created for the exploratory prototype system is available on Moodle, within the 'ArduinoCode' directory. A video of the working prototype is also included in this folder.

D.2 Android Application

The below code for the main implementation, EmotiRun, is also available on Moodle, within the 'AndroidCode' directory. These files can be opened within Android Studio.

D.2.1 Login Screen

```
package testingtime.selfreportingapp;

import android.support.v7.app.AppCompatActivity;
import android.os.Bundle;
import android.content.Intent;
import android.text.Editable;
import android.text.TextWatcher;
import android.view.View;
import android.widget.Button;
import android.widget.CheckBox;
import android.widget.EditText;
import android.media.MediaPlayer;

/*
 *  Landing page for EmotiRun
 *  ~  Gathers a user's name, their weightings for different word pairs,
 *     and allows selection of whether the 'emotional' display is visible or
 *     not
 */
```

```java
public class LandingScreen extends AppCompatActivity {
    private MediaPlayer intervalBeginPlayer;

    private String userName;
    private String displayVisibility = "without display";

    private String weightingValue1;
    private String weightingValue2;
    private String weightingValue3;
    private String weightingValue4;
    private String weightingValue5;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_landing_screen);

        /*
         * Gets the ids of the elements on the screen
         */
        final CheckBox checkBox = (CheckBox)findViewById(R.id.checkBox);
        Button goButton = (Button) findViewById(R.id.goButton);

        EditText nameInput = (EditText)findViewById(R.id.nameInputBox);

        EditText weighting1 = (EditText)findViewById(R.id.weighting1Box);
        EditText weighting2 = (EditText)findViewById(R.id.weighting2Box);
        EditText weighting3 = (EditText)findViewById(R.id.weighting3Box);
        EditText weighting4 = (EditText)findViewById(R.id.weighting4Box);
        EditText weighting5 = (EditText)findViewById(R.id.weighting5Box);

        // Loads the audio recording used on this screen
        intervalBeginPlayer = MediaPlayer.create(LandingScreen.this,
                                   R.raw.intervalbeginstrongtoweak);

        /*
         * Gets the status of the checkbox
         */
        checkBox.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                /*
                 * If the checkbox is ticked when the GO button is pressed,
                 * the 'emotional' display will be visible in this instance
                 * of using EmotiRun
                 */
                if(checkBox.isChecked()) {
                   displayVisibility = "with display";
                }
                else {
                    displayVisibility = "without display";
                }
            }
        });
```

```java
/*
 * Captures a user's name
 */
 nameInput.addTextChangedListener(new TextWatcher() {
    @Override
    public void onTextChanged(CharSequence s, int start, int before,
                                                        int count) {
    }

    @Override
    public void beforeTextChanged(CharSequence s, int start, int
                                                count, int after) {
    }

    @Override
    public void afterTextChanged(Editable enteredText) {
        userName = enteredText.toString();
    }
});

/*
 * Captures the weightings for each word-pair
 */
weighting1.addTextChangedListener(new TextWatcher() {
    @Override
    public void onTextChanged(CharSequence s, int start, int before,
                                                        int count) {
    }

    @Override
    public void beforeTextChanged(CharSequence s, int start, int
                                                count, int after) {
    }

    @Override
    public void afterTextChanged(Editable enteredText) {
        weightingValue1 = enteredText.toString();
    }
});

weighting2.addTextChangedListener(new TextWatcher() {
    @Override
    public void onTextChanged(CharSequence s, int start, int before,
                                                        int count) {
    }

    @Override
    public void beforeTextChanged(CharSequence s, int start, int
                                                count, int after) {
    }

    @Override
    public void afterTextChanged(Editable enteredText) {
        weightingValue2 = enteredText.toString();
    }
});
```

```
weighting3.addTextChangedListener(new TextWatcher() {
    @Override
    public void onTextChanged(CharSequence s, int start, int before,
                                                        int count) {
    }

    @Override
    public void beforeTextChanged(CharSequence s, int start, int
                                                 count, int after) {
    }

    @Override
    public void afterTextChanged(Editable enteredText) {
        weightingValue3 = enteredText.toString();
    }
});

weighting4.addTextChangedListener(new TextWatcher() {
    @Override
    public void onTextChanged(CharSequence s, int start, int before,
                                                        int count) {
    }

    @Override
    public void beforeTextChanged(CharSequence s, int start, int
                                                 count, int after) {
    }

    @Override
    public void afterTextChanged(Editable enteredText) {
        weightingValue4 = enteredText.toString();
    }
});

weighting5.addTextChangedListener(new TextWatcher() {
    @Override
    public void onTextChanged(CharSequence s, int start, int before,
                                                        int count) {
    }

    @Override
    public void beforeTextChanged(CharSequence s, int start, int
                                                 count, int after) {
    }

    @Override
    public void afterTextChanged(Editable enteredText) {
        weightingValue5 = enteredText.toString();
    }
});
```

```
        /*
         * Initiates navigation to the next screen
         */
        goButton.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                goToInputScreen();
            }
        });
    }

    /*
     * Gathers details from this screen that are needed in the next screen
     * of the application
     */
    public void goToInputScreen() {
        Intent intent = new Intent(this, InputScreen.class);

        intervalBeginPlayer.start();

        intent.putExtra("Username",userName);

        intent.putExtra("StrongToWeak",weightingValue1);
        intent.putExtra("HappyToSad",weightingValue2);
        intent.putExtra("EnergeticToTired",weightingValue3);
        intent.putExtra("EnthusiasticToDisinterested",weightingValue4);
        intent.putExtra("RelaxedToNervous",weightingValue5);

        intent.putExtra("DisplayStatus", displayVisibility);

        startActivity(intent);
    }
}
```

D.2.2 Input Screen

```
package testingtime.selfreportingapp;

import android.support.v7.app.AppCompatActivity;
import android.os.Bundle;
import android.os.Handler;
import android.content.Intent;
import android.text.TextUtils;
import android.view.View;
import android.widget.TextView;
import android.widget.Button;
import java.util.ArrayList;
import android.media.MediaPlayer;

/*
 *  Main input screen for EmotiRun
 *  ~  Gathers input for five word-pairs at 40 second intervals,
 *     and if selected on the previous screen an 'emotional' display
 *     is shown
 *  ~  At the end of an interval the collected data is sent in an email
 *     for later analysis
```

```
public class InputScreen extends AppCompatActivity {

    // Array to place the input values for each interval
    private float[] inputArray = new float[]{0,0,0,0,0};
    private float[] weightingArray;

    private ArrayList intervalDataText = new ArrayList();
    private ArrayList intervalDataString = new ArrayList();

    private MediaPlayer intervalBeginPlayer;
    private MediaPlayer happySadPlayer;
    private MediaPlayer energeticTiredPlayer;
    private MediaPlayer enthusiasticDisinterestedPlayer;
    private MediaPlayer relaxedNervousPlayer;
    private MediaPlayer intervalCompletePlayer;
    private MediaPlayer programEndPlayer;

    private int wordPairCount = 0;
    private int intervalCount = 1;
    private float totalWeighting = 0;
    private float inputTotal = 0;
    private String repCalcCheck = "not calculated";

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_input_screen);

        /*
         * Gets the weighting of the word-pairs inputted on the previous
         * screen and places them within an array
         */
        final String wordPair1 =
         getIntent().getExtras().getString("StrongToWeak");
        final String wordPair2 =
         getIntent().getExtras().getString("HappyToSad");
        final String wordPair3 =
         getIntent().getExtras().getString("EnergeticToTired");
        final String wordPair4 =
         getIntent().getExtras().getString("EnthusiasticToDisinterested");
        final String wordPair5 =
         getIntent().getExtras().getString("RelaxedToNervous");

        Float weighting1= Float.parseFloat(wordPair1);
        Float weighting2= Float.parseFloat(wordPair2);
        Float weighting3= Float.parseFloat(wordPair3);
        Float weighting4= Float.parseFloat(wordPair4);
        Float weighting5= Float.parseFloat(wordPair5);

        weightingArray = new
         float[]{weighting1,weighting2,weighting3,weighting4,weighting5};

        /*
         * Gets the ids of the elements on the screen
         */
        final TextView wordPairPart1 =
         (TextView)findViewById(R.id.positiveWordLabel);
```

```
final TextView wordPairPart2 = (TextView)
 findViewById(R.id.negativeWordLabel);

final TextView buttonPressLog = (TextView)
 findViewById(R.id.buttonPressedLog);

final Button stopButton = (Button) findViewById(R.id.stopButton);
final Button emailButton = (Button) findViewById(R.id.emailButton);
final Button endButton = (Button) findViewById(R.id.endButton);

final Button buttonScale5 = (Button)findViewById(R.id.buttonScale5);
final Button buttonScale4 = (Button)findViewById(R.id.buttonScale4);
final Button buttonScale3 = (Button)findViewById(R.id.buttonScale3);
final Button buttonScale2 = (Button)findViewById(R.id.buttonScale2);
final Button buttonScale1 = (Button)findViewById(R.id.buttonScale1);

final Handler handler = new Handler();

/*
 * Loads the audio recordings used on this screen
 */
intervalBeginPlayer = MediaPlayer.create(InputScreen.this,
 R.raw.intervalbeginstrongtoweak);
happySadPlayer = MediaPlayer.create(InputScreen.this,
 R.raw.happytosad);
energeticTiredPlayer = MediaPlayer.create(InputScreen.this,
 R.raw.energetictotired);
enthusiasticDisinterestedPlayer =
 MediaPlayer.create(InputScreen.this,
 R.raw.enthusiastictodisinterested);
relaxedNervousPlayer = MediaPlayer.create(InputScreen.this,
 R.raw.relaxedtonervous);
intervalCompletePlayer = MediaPlayer.create(InputScreen.this,
 R.raw.intervalcomplete);
programEndPlayer = MediaPlayer.create(InputScreen.this,
 R.raw.programend);

stopButton.setOnClickListener(new View.OnClickListener() {
    @Override
    public void onClick(View v) {
        final Button greenLight = (Button)
         findViewById(R.id.greenLight);
        final Button amberLight = (Button)
         findViewById(R.id.amberLight);
        final Button redLight = (Button)
         findViewById(R.id.redLight);

        /*
         * Hides all the features on the screen so the user can no
         * longer provide input
         */
        buttonScale5.setVisibility(View.INVISIBLE);
        buttonScale4.setVisibility(View.INVISIBLE);
        buttonScale3.setVisibility(View.INVISIBLE);
        buttonScale2.setVisibility(View.INVISIBLE);
        buttonScale1.setVisibility(View.INVISIBLE);
        greenLight.setVisibility(View.INVISIBLE);
        amberLight.setVisibility(View.INVISIBLE);
```

```
            redLight.setVisibility(View.INVISIBLE);
            wordPairPart1.setVisibility(View.INVISIBLE);
            wordPairPart2.setVisibility(View.INVISIBLE);
            buttonPressLog.setVisibility(View.INVISIBLE);
            stopButton.setVisibility(View.INVISIBLE);

            emailButton.setVisibility(View.VISIBLE);

            // Stops interval timer
            handler.removeMessages(0);

            programEndPlayer.start();
        }
    });

    /*
     * Gathers data and sends this as an email for later analysis
     */
    emailButton.setOnClickListener(new View.OnClickListener() {
        @Override
        public void onClick(View v) {
            // Gets data input from previous screen
            String userName =
             getIntent().getExtras().getString("Username");
            String displayOption =
             getIntent().getExtras().getString("DisplayStatus");

            String intervalDataSet = TextUtils.join("; ",
             intervalDataString);

            Intent emailIntent = new Intent(Intent.ACTION_SEND);

            // Destination email address
            emailIntent.putExtra(Intent.EXTRA_EMAIL, new
             String[]{"username@gmail.com"});
            // Participant name
            emailIntent.putExtra(Intent.EXTRA_SUBJECT, userName);
            // Interval data, weightings and display option
            emailIntent.putExtra(Intent.EXTRA_TEXT, intervalDataSet + ",
             WEIGHTINGS: " + wordPair1 + ", " + wordPair2 + ", " +
             wordPair3 + ", " + wordPair4 + ", " + wordPair5 + ",
             DISPLAY SETTING: " + displayOption + ".");

            emailIntent.setType("message/rfc822");
            startActivity(Intent.createChooser(emailIntent, "Choose
             email client..."));

            endButton.setVisibility(View.VISIBLE);
        }
    });

    endButton.setOnClickListener(new View.OnClickListener() {
        @Override
        public void onClick(View v) {
            backToLandingScreen();
        }
    });
```

```
/*
 * Listens to see which button has been pressed for each word-pair
 */
buttonScale5.setOnClickListener(new View.OnClickListener() {
    @Override
    public void onClick(View v) {
        // The value of the button pressed multiplied by the
        // weighting given to the current word-pair is logged in the
        // inputArray
        inputArray[wordPairCount] = 5 *
                                  weightingArray[wordPairCount];

        // If input is not collected for all word-pairs for an
        // interval the average is calculated for the word-pairs
        // recorded, and their associated weightings. A
        // totalWeighting array is needed for this purpose
        totalWeighting += weightingArray[wordPairCount];

        // Checks if it is the start of an interval to add
        // appropriate heading text to the data string
        newIntervalCheck();

        // Adds input value to the data string
        intervalDataText.add(inputArray[wordPairCount] + ", ");

        wordPairCount++;

        // Checks what step is next and starts the appropriate audio
        // or executes the appropriate calculation
        checkNextStep();

        // Updates a text label so the user is aware that their
        // button press has been logged
        buttonPressLog.append("Button 1 pressed \n");
    }
});

buttonScale4.setOnClickListener(new View.OnClickListener() {
    @Override
    public void onClick(View v) {
        inputArray[wordPairCount] = 4 *
                                  weightingArray[wordPairCount];
        totalWeighting += weightingArray[wordPairCount];
        newIntervalCheck();
        intervalDataText.add(inputArray[wordPairCount] + ", ");
        wordPairCount++;
        checkNextStep();
        buttonPressLog.append("Button 2 pressed \n");
    }
});

buttonScale3.setOnClickListener(new View.OnClickListener() {
    @Override
    public void onClick(View v) {
        inputArray[wordPairCount] = 3 *
                                  weightingArray[wordPairCount];
        totalWeighting += weightingArray[wordPairCount];
        newIntervalCheck();
```

```
                intervalDataText.add(inputArray[wordPairCount] + ", ");
                wordPairCount++;
                checkNextStep();
                buttonPressLog.append("Button 3 pressed \n");
            }
        });

        buttonScale2.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                inputArray[wordPairCount] = 2 *
                                              weightingArray[wordPairCount];
                totalWeighting += weightingArray[wordPairCount];
                newIntervalCheck();
                intervalDataText.add(inputArray[wordPairCount] + ", ");
                wordPairCount++;
                checkNextStep();
                buttonPressLog.append("Button 4 pressed \n");
            }
        });

        buttonScale1.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                inputArray[wordPairCount] = 1 *
                                              weightingArray[wordPairCount];
                totalWeighting += weightingArray[wordPairCount];
                newIntervalCheck();
                intervalDataText.add(inputArray[wordPairCount] + ", ");
                wordPairCount++;
                checkNextStep();
                buttonPressLog.append("Button 5 pressed \n");
            }
        });

        /*
         * 40 second timer for each interval
         */
        handler.postDelayed(new Runnable() {
            @Override
            public void run() {
                // Executes operations every 40 seconds
                handler.postDelayed(this, 40000);

                runOnUiThread(new Runnable() {
                    public void run() {
                        intervalBeginPlayer.start();

                        wordPairPart1.setText("Strong");
                        wordPairPart2.setText("Weak");

                        // If no input has been entered for the interval
                        if (wordPairCount==0) {
                            // Adds the interval heading text and notes that
                            // no data was captured
                            newIntervalCheck();
                            intervalDataText.add("None, ");
                        }
```

```
                        /*
                         * If input has not been gathered for all word-pairs
                         * for an interval then no 'emotional display' will
                         * have been shown
                         * Therefore, at the end of the interval the
                         * representation calculation is made with the input
                         * recorded
                         */
                        if (!repCalcCheck.equals("calculation done")) {
                            repCalcCheck = "calculation to be made without
                                                                all inputs";
                            representationFunction();
                        }

                        // Resets the variables and the display
                        wordPairCount = 0;
                        inputTotal = 0;
                        totalWeighting = 0;
                        repCalcCheck = "not calculated";
                        buttonPressLog.setText("");

                        buttonScale5.setVisibility(View.VISIBLE);
                        buttonScale4.setVisibility(View.VISIBLE);
                        buttonScale3.setVisibility(View.VISIBLE);
                        buttonScale2.setVisibility(View.VISIBLE);
                        buttonScale1.setVisibility(View.VISIBLE);

                        wordPairPart1.setVisibility(View.VISIBLE);
                        wordPairPart2.setVisibility(View.VISIBLE);
                    }
                });
            }
        }, 40000);
    }

    /*
     * Navigates back to the start screen
     */
    public void backToLandingScreen() {
        Intent intent = new Intent(this, LandingScreen.class);

        startActivity(intent);
    }

    /*
     * Checks if it is the start of an interval
     */
    public void newIntervalCheck() {
        if (wordPairCount == 0)
        {
            // Adds text to the data string to signify the start of an
            // interval
            intervalDataText.add("INTERVAL " + (intervalCount) + ",Input:");
        }
    }
```

```java
/*
 * Checks which operation is next, and plays the appropriate audio
 * recording to alert the user
 */
public void checkNextStep() {
    final TextView wordPart1 =
     (TextView)findViewById(R.id.positiveWordLabel);
    final TextView wordPart2 = (TextView)
     findViewById(R.id.negativeWordLabel);
    final int delay = 1000;

    switch(wordPairCount) {
        // Plays the audio recording of the next word-pair to alert the
        // user to provide input
        // ~ Text labels highlighting which word-pair input should be
        // provided for are updated
        case 1 :
            Handler handler = new Handler();
            handler.postDelayed(new Runnable() {
                @Override
                public void run() {
                    happySadPlayer.start();
                }
            }, delay);

            wordPart1.setText("Happy");
            wordPart2.setText("Sad");

            break;

        case 2:
            Handler handler2 = new Handler();
            handler2.postDelayed(new Runnable() {
                @Override
                public void run() {
                    energeticTiredPlayer.start();
                }
            }, delay);

            wordPart1.setText("Energetic");
            wordPart2.setText("Tired");

            break;

        case 3:
            Handler handler3 = new Handler();
            handler3.postDelayed(new Runnable() {
                @Override
                public void run() {
                    enthusiasticDisinterestedPlayer.start();
                }
            }, delay);

            wordPart1.setText("Enthusiastic");
            wordPart2.setText("Disinterested");

            break;
```

```
            case 4:
                Handler handler4 = new Handler();
                handler4.postDelayed(new Runnable() {
                    @Override
                    public void run() {
                        relaxedNervousPlayer.start();
                    }
                }, delay);

                wordPart1.setText("Relaxed");
                wordPart2.setText("Nervous");

                break;

            case 5:
                final Button buttonScale5 = (Button)
                 findViewById(R.id.buttonScale5);
                final Button buttonScale4 = (Button)
                 findViewById(R.id.buttonScale4);
                final Button buttonScale3 = (Button)
                 findViewById(R.id.buttonScale3);
                final Button buttonScale2 = (Button)
                 findViewById(R.id.buttonScale2);
                final Button buttonScale1 = (Button)
                 findViewById(R.id.buttonScale1);

                // Makes the input buttons and word-pair text labels
                // invisible so a user may no longer provide input
                buttonScale5.setVisibility(View.INVISIBLE);
                buttonScale4.setVisibility(View.INVISIBLE);
                buttonScale3.setVisibility(View.INVISIBLE);
                buttonScale2.setVisibility(View.INVISIBLE);
                buttonScale1.setVisibility(View.INVISIBLE);

                wordPart1.setVisibility(View.INVISIBLE);
                wordPart2.setVisibility(View.INVISIBLE);

                representationFunction();
        }
    }

    /*
     * Calculation for the 'emotional' display with the corresponding
     * 'light' combination shown
     */
    public void representationFunction() {
        final Button greenLight = (Button) findViewById(R.id.greenLight);
        final Button amberLight = (Button) findViewById(R.id.amberLight);
        final Button redLight = (Button) findViewById(R.id.redLight);

        // Adds the values recorded for the current interval
        for (int i = 0; i < 5; ++i) {
            inputTotal += inputArray[i];
        }
```

```
// Calculates an average of the inputted data for the interval
// and adds this to the data string
inputTotal = inputTotal / totalWeighting;

intervalDataText.add("Input AVERAGE: " + inputTotal + ",");

// Displays the light representation if selected
String displayOption =
          getIntent().getExtras().getString("DisplayStatus");

/*
 * Using the calculated average a given combination of differing
 * coloured 'lights' are displayed
 * (if the display option is set as visible)
 */
if (inputTotal >= 0 && inputTotal <= 1) {
    if (displayOption.equals("with display")) {
        greenLight.setVisibility(View.INVISIBLE);
        amberLight.setVisibility(View.INVISIBLE);
        redLight.setVisibility(View.VISIBLE);
    }

    // Logs the light display shown for later analysis
    intervalDataText.add("Representation: R");
}
else if (inputTotal <= 2) {
    if (displayOption.equals("with display")) {
        greenLight.setVisibility(View.INVISIBLE);
        amberLight.setVisibility(View.VISIBLE);
        redLight.setVisibility(View.VISIBLE);
    }

    intervalDataText.add("Representation: A/R");
}
else if (inputTotal <= 3) {
    if (displayOption.equals("with display")) {
        greenLight.setVisibility(View.INVISIBLE);
        amberLight.setVisibility(View.VISIBLE);
        redLight.setVisibility(View.INVISIBLE);
    }

    intervalDataText.add("Representation: A");
}
else if (inputTotal <= 4) {
    if (displayOption.equals("with display")) {
        greenLight.setVisibility(View.VISIBLE);
        amberLight.setVisibility(View.VISIBLE);
        redLight.setVisibility(View.INVISIBLE);
    }

    intervalDataText.add("Representation: G/A");
}
else if (inputTotal <= 5) {
    if (displayOption.equals("with display"))
    {
        greenLight.setVisibility(View.VISIBLE);
        amberLight.setVisibility(View.INVISIBLE);
```

```
                redLight.setVisibility(View.INVISIBLE);
            }

            intervalDataText.add("Representation: G");
        }
        else {
            if (displayOption.equals("with display")) {
                greenLight.setVisibility(View.INVISIBLE);
                amberLight.setVisibility(View.INVISIBLE);
                redLight.setVisibility(View.INVISIBLE);
            }

            intervalDataText.add("Representation: None");
        }

        // Adds interval data to the main data string and resets the text
        // string
        String joinedIntervalDataText = TextUtils.join(" ",
                                                   intervalDataText);
        intervalDataString.add(joinedIntervalDataText);
        intervalDataText = new ArrayList();

        intervalCount++;

        // If all inputs have been entered before the current interval has
        // timed out then the user is alerted of the completion of the
        // interval
        if (!repCalcCheck.equals("calculation to be made without all
                                                             inputs")) {
            intervalCompletePlayer.start();
        }

        repCalcCheck = "calculation done";
    }
}
```